NEW SERIES.)

No. 6.

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA.

FIRST REPORT OF THE ANTI-MALARIAL OPERATIONS AT MIAN MIR, 1901-1903.

BY

CAPTAIN S. P. JAMES, M.B. (LOND.), I.M.S.
(*On Special Duty.*)

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1903.

Price 12 Annas or 1s. 2d.

No. 6.

(NEW SERIES.)

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA.

FIRST REPORT OF THE ANTI-MALARIAL OPERATIONS AT MIAN MIR, 1901-1903.

BY

CAPTAIN S. P. JAMES, M.B. (LOND.), I.M.S.

(On Special Duty.)

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.

1903.

Agents for the Sale of Books published by the Superintendent of Government Printing, India, Calcutta.

IN ENGLAND.

E. A. ARNOLD, 37, Bedford Street, Strand, London, W.C.

CONSTABLE & CO., 2, Whitehall Gardens, London, S.W.

SAMPSON LOW, MARSTON & CO., St. Dunstan's House, Fetter Lane, London, E.C.

P. S. King & SON, 2 & 4, Great Smith Street, Westminster, London, S.W.

LUZAC & CO., 46, Gerat Russell Street, London, W.C.

KEGAN PAUL, TRENCH, TRÜBNER & CO., Charing Cross Road, London, W.C.

BERNARD QUARITCH, 15, Piccadilly, London, W.

WILLIAMS and NORGATE, Oxford.

DEIGHTON BELL & CO., Cambridge.

ON THE CONTINENT.

R. FRIEDLANDER & SOHN, 11, Carlstrasse, Berlin, N.W.

OTTO HARRASSOWITZ, Leipzig.

KARL W. HIERSEMANN, Leipzig.

ERNEST LEROUX, 28, Rue Bonaparte, Paris.

MARTINUS NIJHOFF, The Hague.

IN INDIA.

THACKER, SPINK & CO., Calcutta and Simla.

NEWMAN & CO., Calcutta.

R. CAMBRAY & CO., Calcutta.

S. K. LAHIRI & CO., Calcutta.

THACKER & CO., LD., Bombay.

D. B. TARAPOREVALA, SONS & CO., Bombay.

A. J. COMBRIDGE & CO., Bombay.

RADHABAI ATMARAM SAGOON, Bombay.

HIGGINBOTHAM & CO., Madras.

V. KALYANARAMA IYER & CO., Madras.

G. A. NATESAN & CO., Madras.

RAI SAHIB M. GULAB SINGH AND SONS, Mufid-i-Am Press, Lahore.

N. B. MATHUR, Superintendent, Nazair Kanun Hind Press, Allahabad.

Superintendent, American Baptist Mission Press, Rangoon.

FIRST REPORT OF THE ANTI-MALARIAL OPERATIONS AT MIAN MIR, 1901-1903.

PART I.—General. | PART II.—Operations.
PART III.—Results.

PART I.

THE operations to be described in this report were initiated by the members of the Royal Society's Malaria Commission, with the object of demonstrating in an experimental way that malarial fevers can be prevented by practical measures based on the discovery that a particular kind of mosquito is the definitive host of the malaria parasite.

The original object of the Commissioners was to test the efficacy of mosquito destruction in the prevention of malaria, and it was necessary, therefore, to select a station in which it seemed probable that a marked reduction in the number of mosquitoes could be effected. It was also desirable to choose a very malarious station, in order that the results of the experiments might be more evident. From both these points of view the cantonment of Mian Mir appeared to be suitable, for as regards the possibility of reducing the number of mosquitoes it seemed probable that, as the rainy season was short and the total annual rainfall small, the majority of breeding places could be dealt with comparatively easily; and as regards the prevalence of malaria, this cantonment is recognised as being one of the most unhealthy in the Punjab.

Mian Mir cantonment is situated on a level plain six miles to the south-east of Lahore city and about four miles to the east of the civil station. The locality was selected in 1851-52 when it was decided to abandon the former cantonments at Anarkali (in Lahore) on account of their unhealthiness. The new cantonment was at that time a treeless desert, but many trees have since been planted, and in all parts to which irrigation extends, good gardens and grass land have been laid out.

The ordinary garrison of the cantonment consists of—

2 Batteries of Royal Field Artillery.
1 Regiment of British Infantry.
1 Regiment of Bengal Cavalry.
1 Regiment of Punjab Pioneers.
1 Regiment of Native Infantry.

The total number of officers and men of these regiments averages about 3,900, and in connection with the ambulance and transport establishments there are in addition about 600 native followers.

The arrangement of the cantonment is as follows:—On the extreme north is the bazaar of the British Infantry and to the south-west of it is their hospital. To the south of the hospital are the lines of the European Infantry and the rifle range, and to the east by south of the range are the Quarter Guard, the Magazine, and a set of officers' quarters. Still further to the south are the racket court and Executive Engineer's office to the east of which are the lines of the Native Infantry. To the south of these again are the lines of the Royal Artillery and at the extreme south of the cantonment the lines of the Native Cavalry.

The average annual rainfall in Mian Mir is about 20 inches. The following table giving the average rainfall for each month of the years 1868 to 1892 shows the distribution of the rainfall throughout the year:—

Month.	Average rainfall in inches.
January	·6
February	1·1
March	·6
April	·4
May	·8
June	1·5
July	5·7
August	4·6
September	2·0
October	·3
November	·1
December	·5

The greatest amount of rain falls therefore from June to September, the chief fall being in July. The hottest month of the year is June, the temperature in a carefully shut house in that month varying from 96°—106° F. and unless rain comes, the heat lasts on into July.

The hot weather indicates its approach in April, but indoors it is fairly comfortable until May. Then the air becomes very dry, and hot burning winds commence. The nights are warm but not troublesome during May, and both April and May are comparatively healthy months for Europeans. In June the

heat increases considerably and hot winds are prevalent. Early in July there is a burst of the monsoon rain, but owing to its short duration its cooling effect only lasts for a few days, and unless more rain comes, the great heat begins again and is made more trying by the increased moisture of the air. Throughout July and August the nights are very hot, and in the latter month strong hot breezes sometimes spring up. In September the nights begin to be less hot and from September 15th the days also are distinctly cooler. Early in October it is quite cool out of doors, and by the middle of this month the weather becomes very pleasant. This, however, is the month when malarial fevers are most prevalent. November and December days are bright and clear and the nights cold. In January and February early morning frosts are noticeable. March is very variable but generally pleasant, and in April the hot weather begins to make itself felt again.

The European troops are housed in lofty one-storied stone buildings provided with a wide verandah and raised some feet off the ground. In the hot weather punkahs are provided by day and night.

The drinking water for the troops is derived from the main irrigation canal. After passing through filter beds it is distributed to different parts of the cantonment in pipes. Many of the natives, however, obtain their drinking water from wells, of which there are a large number in the cantonment.

One of the worst features of Mian Mir as a cantonment is the fact that the plain on which it is situated is so level that very little of the surface water can drain away. Throughout the cantonment there are numerous brickwork surface drains, but in none of these is there sufficient fall, and the majority end abruptly on the level plain. In the construction of these storm-water drains there appears to have been no definite object, and they are indeed of more harm than good, for whenever a slight shower of rain falls, they become full of water which remains in them until dried up by the sun. For this reason they form, during the rainy season, favourable breeding places of *anopheles* mosquitoes.

The surface layer of the soil consists for the most part of very dry finely powdered mud and sand, which, during the fierce winds of the hot weather, is blown about in clouds of dust. Beneath this superficial layer the soil consists for the most part of clay and "*kankar*"—a soil which becomes hard and impervious on treatment with water.

In consequence of the sub-soil being for the most part impervious to water, after one or two hours' rain the appearance of the cantonment is changed from that of a dry arid plain to that of a district in flood. Broad expanses of water often a quarter of a mile in extent cover the plain on every side, and the inhabitants of the followers' huts on some of the comparatively low-lying parts are literally flooded out. The majority of these large expanses of water dry up in the hot sun in three or four days, but numerous small deeper pools are left

which, lasting for a week or ten days, form excellent breeding places of *anopheles* mosquitoes.

In the absence of irrigation, Mian Mir would be little better than an arid desert during the greater part of the year. A branch of the main irrigation canal enters the cantonment and from this numerous shallow channels (irrigation watercourses or "cuts") convey water to all the gardens, grass land, and crops in the cantonment. The water is drawn up from these channels by means of Persian wheels ("*jalahars*") and distributed over the land in shallow ditches. No crops requiring continuous irrigation are grown in the cantonment, and the plan usually adopted is to water a certain area of land one day and another the next, so that all the water has time to soak into the ground or dry up before the next supply is given. In the garden portions the Persian wheels are usually worked for about three hours daily, and all the water used has generally soaked into the ground by the same evening. At certain times of the year the supply of water is frequently shut off for ten days or more at a time.

This is shown in the following table :—

Table showing the number of days of each month during which irrigation water was supplied to Mian Mir Cantonment for some years between 1892 and 1901.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892 . . .	16	13	23	24	26	28	13	14	22	30	30	31
1893 . . .	3	0	4	22	21	25	28	31	22	30	0	0
1897 . . .	11	4	22	28	31	29	31	31	30	23	20	18
1898 . . .	7	7	21	30	31	30	29	31	30	21	20	20
1899 . . .	10	19	26	25	31	30	31	31	21	14	10	14
1900 . . .	0	9	22	27	31	21	28	14	19	28	21	15
1901 . . .	3	0	27	27	30	23	28	21	30	20	16	7

Before anti-malarial operations in a place can be carried out with any hope of success, it is necessary to have exact knowledge of the real prevalence of malaria in the place, and of the conditions on which this prevalence depends.

Before commencing operations in Mian Mir, therefore, we spent some time in a study of the prevalence of malaria there and the conditions which determine it.

As will be seen from the following table, Mian Mir is one of the most unhealthy cantonments in this part of India:—

Table showing the mean annual admission rate (per 1,000 of average strength) for ague among European troops for the years 1896—1900, inclusive, in some stations of the Punjab and United Provinces.*

Mian Mir	663·0	Delhi	1,145·6
Sialkot	271·0	Meerut	477·2
Rawalpindi	289·0	Fatehgarh	464·4
Amritsar	445·6	Cawnpore	294·5
Jullundur	260·9	Lucknow	204·3
Ferozpore	760·6	Fyzabad	231·2
Umballa	289·8	Fort Allahabad	400·6
Jhansi	355·7	Benares	273·2
Agra	259·0		

The number of admissions per 1,000 for malarial fevers among European troops at Mian Mir during the year 1901 is shown in the following table:—

EUROPEAN TROOPS AT MIAN MIR.

MALARIAL FEVERS (AGUE AND REMITTENT).

Admitted per 1,000.

YEAR.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901	152·0	68·3	69·5	63·4	159·4	141·4	63·5	136·9	153·1	219·8	134·3	62·8

From this table it would appear that malarial fevers are prevalent in Mian Mir throughout the year. This is not, however, the case, and a large number of the cases recorded in the hospital returns are doubtless due to relapses. It is certain also that other diseases than malaria are often returned under intermittent or remittent malarial fevers. In order to ascertain what proportion of the admissions for malarial fevers were really due to malaria, a number of men admitted for these diseases were examined in October 1901 by Dr. Christophers, and in 40 *per cent.* of the cases examined, malarial parasites were found. In the same way I examined a number of men admitted or detained for malaria during September 1902 before any quinine had been administered to them, and found malarial parasites in 45 *per cent.* of the cases. During this month also, through the courtesy of Major Gordon Hall, R.A.M.C., no quinine was administered as medicine to a number of cases of "fever" in which I had not found parasites. All of them recovered in from one to three days without any quinine treatment, and from this fact and the fact that several examinations of each case failed to show the presence of parasites, I conclude that these cases of fever were not due to malaria, though usually entered as such in the returns. The temperature charts of some of these cases are given in an appendix to this report (Appendix A).

* The term "ague" in this report includes only intermittent malarial fevers. The term "malaria fevers" is used to include intermittent and remittent malarial fevers.

The following tables exhibit the great variations which occur in the admission rates for malarial fevers at Mian Mir in different years:—

EUROPEAN TROOPS AT MIAN MIR.

MALARIAL FEVERS (AGUE AND REMITTENT).

Admitted per 1,000.

YEARS.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892 . . .	56·8	41·4	46·7	40·3	55·6	62·2	57·3	149·3	110·9	165·9	196·7	123·5
1893 . . .	54·2	35·0	55·4	41·2	74·6	109·7	156·9	142·6	81·0	134·3	102·4	88·3
1894 . . .	49·1	14·1	7·4	3·9	56·1	58·1	85·3	146·0	203·9	332·5	223·5	193·0
1895 . . .	118·2	84·1	106·3	189·1	152·9	174·9	143·9	127·6	125·0	148·0	166·4	32·7
1896 . . .	12·1	3·9	6·7	14·1	10·8	43·5	33·7	9·6	47·2	87·5	37·0	28·9
1897 . . .	10·6	17·2	23·5	12·3	14·9	15·2	23·5	19·8	106·0	58·4	284·8	186·9
1898 . . .	84·5	33·	30·4	45·0	68·9	5·3	24·0	10·8	86·8	209·1	126·0	97·8
1899 . . .	33·0	37·6	38·6	36·8	80·7	56·7	50·8	29·8	58·2	49·9	18·0	6·6
1900 . . .	15·4	9·0	21·7	24·5	11·1	16·2	9·3	29·7	138·8	356·4	261·3	229·1
1901 . . .	152·0	68·3	69·5	63·4	159·4	141·4	63·5	126·9	153·1	219·8	134·3	62·8

NATIVE TROOPS AT MIAN MIR.

MALARIAL FEVERS.

Admitted per 1,000.

YEARS.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892 . . .	25·7	12·6	17·1	26·0	33·0	14·2	3·6	31·3	52·2	88·0	54·0	16·1
1893 . . .	6·8	4·9	4·2	6·2	8·2	7·3	15·2	46·5	15·2	27·9	19·9	34·3
1894 . . .	28·3	21·4	6·3	16·8	14·2	8·7	25·4	47·8	91·7	136·6	40·2	30·9
1895 . . .	4·6	1·3	4·0	13·7	23·0	7·7	28·7	37·5	120·9	146·3	21·2	19·5
1896 . . .	8·5	5·2	7·6	4·2	4·3	8·3	18·2	12·9	13·7	13·1	13·8	4·4
1897 . . .	3·5	1·0	2·7	5·8	10·6	10·4	11·1	20·3	75·5	119·0	141·2	48·3
1898 . . .	16·2	9·0	11·1	13·9	27·6	35·9	22·6	113·6	100·5	219·0	160·3	42·7
1899 . . .	20·8	10·5	16·4	13·6	20·0	6·8	19·9	12·3	8·4	17·8	19·9	9·2
1900 . . .	8·1	2·3	6·9	18·1	28·0	23·2	12·4	23·0	55·9	178·8	88·9	114·5
1901 . . .	49·8	21·2	14·6	47·7	67·9	42·3	32·2	26·5	43·4	114·4	43·9	22·7

It is probable that these variations are not altogether due to differences in the prevalence of malaria in different years, but to the fact that some medical officers are much more careful in their diagnosis of cases than others, as well as to the fact that some medical officers "detain"* slight cases of fever, while others

* Detained cases are not shown in the official returns.

"admit" every case at once. For these reasons the statistics of any individual year may not by any means represent accurately the real prevalence of the disease.

A more reliable method of estimating the prevalence of malarial fevers and the liability to infection is given, as was originally shown by Koch, by an examination of young children, in order to find the percentage infected with malarial parasites. Doctors Stephens and Christophers have added to this method the estimation of the percentage of *anopheles* mosquitoes infected with sporozoites in the salivary glands, as indicating more accurately the actual danger of infection. Every cantonment in India has a number of followers' lines and native bazaars attached to it, and the examination of the children and of the *anopheles* mosquitoes in these lines and bazaars affords a ready means of estimating accurately the prevalence of malaria and the liability to infection.

The following table shows the results of the examinations of children in the different bazaars of Mian Mir made in October and November 1901 :—

TABLE SHOWING THE PREVALENCE OF MALARIA IN MIAN MIR.

Locality.	Time of year.	Percentage of children infected with malaria parasites. (Endemic Index.)	Percentage with enlarged spleens.
British Infantry Bazar	October 1901.	52	80
Royal Artillery Bazaar	Do.	35	75
Native Cavalry lines	Do.	25	36
Syce lines (A)	November 1901.	56·5	48
Syce lines (B)	Do.	20	20

The endemic index of some of these bazaars is a high one, and it is evident that, in the months in which the examinations were made, malarial fevers are very prevalent in Mian Mir and the liability to infection very great.

In order to ascertain correctly the seasonal variations in the prevalence of malaria at Mian Mir I have examined a number of the children in the bazaars as frequently as possible throughout the year, and these results together with those obtained last year may be tabulated as follows :—

TO SHOW THE SEASONAL PREVALENCE OF MALARIA IN MIAN MIR.

Locality.	Date.	Endemic Index.	Spleen rate. per cent.	Number examined.
British Infantry Bazaar . .	October 5th, 1901 .	52	80	25
	November 25th, 1901 .	20	38	25
	June 17th, 1902 . .	8·3	26	24
	July 28th, 1902 . .	8·5	37	35
	August 25th, 1902 .	15	60	20
	September 17th, 1902 .	32·2	65	31
	October 22nd, 1902 .	42·3	69	29
	November 19th, 1902 .	27	57	24

From a consideration of the above table we may say that the season of new infections in Mian Mir begins at the end of July or the beginning of August, and that the number of new infections increases steadily until it reaches a maximum in October. As soon as the endemic index begins to decrease it may be assumed that new infections have ceased, and the sudden fall in the percentage of infected children in November affords a proof of this. From November until July of the next year any cases that occur are relapses of former infections.*

In considering the factors on which the prevalence of malarial fevers in Mian Mir depends, the influence of the presence of *anopheles* mosquitoes is of most importance. After determining the endemic indices of the bazaars in October 1901 our next object therefore was to find infection in *anopheles* mosquitoes.

Only two species of *anopheles* were at all abundant, *viz.* : *A. Rossi* (Giles) and *A. culicifacies* (Giles). Other species, which will be referred to later, were present, but not in large numbers. *A. Rossi* was more abundant than *A. culicifacies*, but both species were found in all the bazaars, in the barracks of the troops and in the hospital and jail.

In view of the fact that our previous work in India had led us to the conclusion that *A. Rossi* was a very inefficient carrier of malaria under natural conditions, while *A. culicifacies* was a very good one, we selected a bazaar for the examination of *anopheles* mosquitoes where the two species could be caught in fair numbers in the same houses, in order to compare their rates of infection.

The results of our dissections were as follow :—

Species of *Anopheles*.	Number dissected.	Number with sporozoites in the glands.	Percentage infected with sporozoites.
A. Rossi	496	0	0
A. culicifacies	259	12	4·6

It is evident from these results that *A. culicifacies* is the chief if not the only carrier of malaria in Mian Mir, and the knowledge that *A. Rossi* takes little or no part in the communication of infection under natural conditions, is of great importance in connection with anti-malarial operations.

* In Chart II the seasonal prevalence of malarial fevers in Mian Mir as given by the statistics of admissions into hospital may be compared with the results shown in this table. It will be seen that although the statistics of any one year taken separately give but little idea of the seasonal prevalence of malaria, if the decennial monthly rates are taken, the result corresponds very accurately with that obtained from the examination of children. The comparison of the fever curves in this chart shows also that the rise in the admission rates for fevers in September and October is really due to malaria and not to any other cause.

Six species of *anopheles* mosquitoes have been found by us in Mian Mir, *viz.*:—

A. Rossi.	*A. pulcherrimus.*
A. culicifacies.	*A. fuliginosus.*
A. Stephensi.	*A. nigerrimus.*

The seasonal prevalence of these species in 1901-1902 was as follows. All the species were found during October and the first week of November 1901. *A. Rossi* was exceedingly abundant and almost any number could be caught with ease in all the bazaars and barracks. *A. culicifacies* was also present in fair numbers though not so plentiful as *A. Rossi*. All the other species were comparatively rare, and it would have taken many weeks to catch a sufficient number of any of these species to render their dissection of advantage. During the second week of November the number of adult *anopheles* mosquitoes began to decrease rapidly, and November 28th was the last date on which any adult *A. culicifacies* were caught in the houses. Two adult *A. Rossi* were caught in one of the bazaars on December 5th after an hour's search, but these were the last adults seen during the winter of 1901, though search was frequently made during December. The larvæ also diminished very rapidly, but a few were still present in some old pools on December 20th, and in pools which remained without drying up throughout the winter, a certain number of larvæ of *A. culicifacies* could always be found, though no adult insects appeared to be present in the houses. In newly formed pools, however, no larvæ appeared, and it is probable that larvæ found during the winter in Mian Mir are old ones which remain alive, but are unable to develop into adults until the spring.

A few new larvæ could be found in March but adult *anopheles* mosquitoes were so few that it was difficult or impossible to detect them in the houses. Indeed it was not until the middle of May that adult mosquitoes of this genus became sufficiently numerous in the houses to be detected by searching, and until this time larvæ also were scanty though gradually increasing in numbers.* From the middle of May onwards the number of larvæ and the number of adult insects increased steadily to a maximum in September and the beginning of October. In November the numbers again began to diminish rapidly. The seasonal prevalence of the two species *A. culicifacies* and *A. Rossi* does not exactly correspond. *A. culicifacies* appears much earlier than *A. Rossi*. Although moderate numbers of *A. culicifacies* could be caught in the bazaars during May and June, not a single adult *A. Rossi* was found until the beginning of July. As soon, however, as this species appears it increases very rapidly, and in a short time becomes far more abundant than any other species. This difference in seasonal prevalence may be accounted for by the fact that whereas *A. culicifacies* breeds chiefly

* Observations on the methods by which *anopheles* mosquitoes tide over the winter and reappear in the spring will be found in Part II.

in the irrigation watercourses which are running more or less throughout the year, *A. Rossi* is dependent for its breeding grounds chiefly on rain-formed pools, so that it does not appear in any abundance until the heavy rains of July commence.

This connection between the flow of the irrigation water-supply and the prevalence of *Anopheles culicifacies* and between the rainfall and the prevalence of *Anopheles Rossi* is shown in the following chart :—

(Chart No. I.)

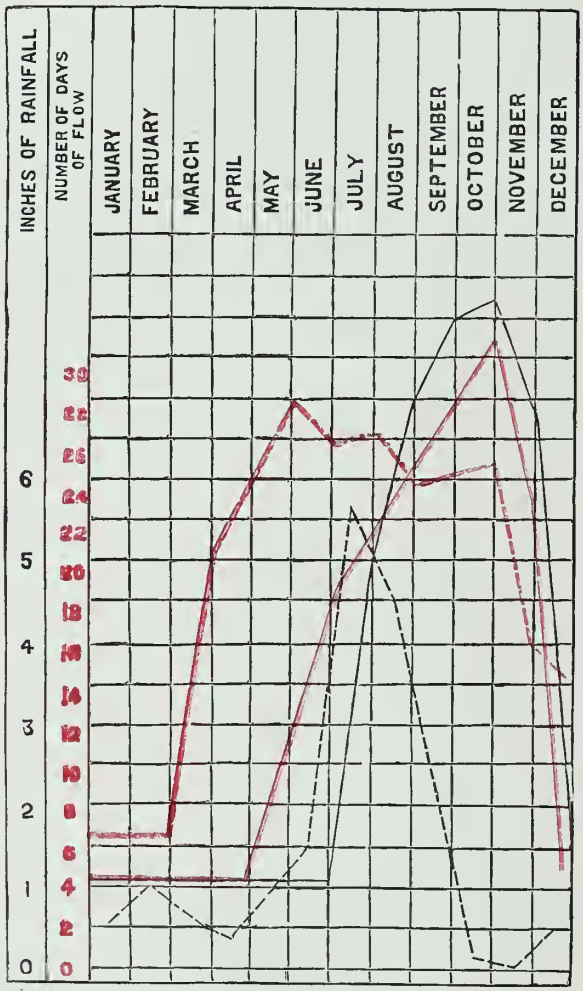


Chart No. 1. Red dotted line=curve of irrigation water-supply to Mian Mir (average of 7 years, *vide* table on page 4).

Red line=curve of *A. culicifacies*.

Black dotted line=curve of rainfall (average 1868—1892, *vide* table on page 2).

Black line=curve of *A. Rossi*.

By means of the following chart the seasonal prevalence of *anopheles* mosquitoes, of malarial fevers, and the rainfall in Mian Mir may now be compared:—

(Chart No. II.)

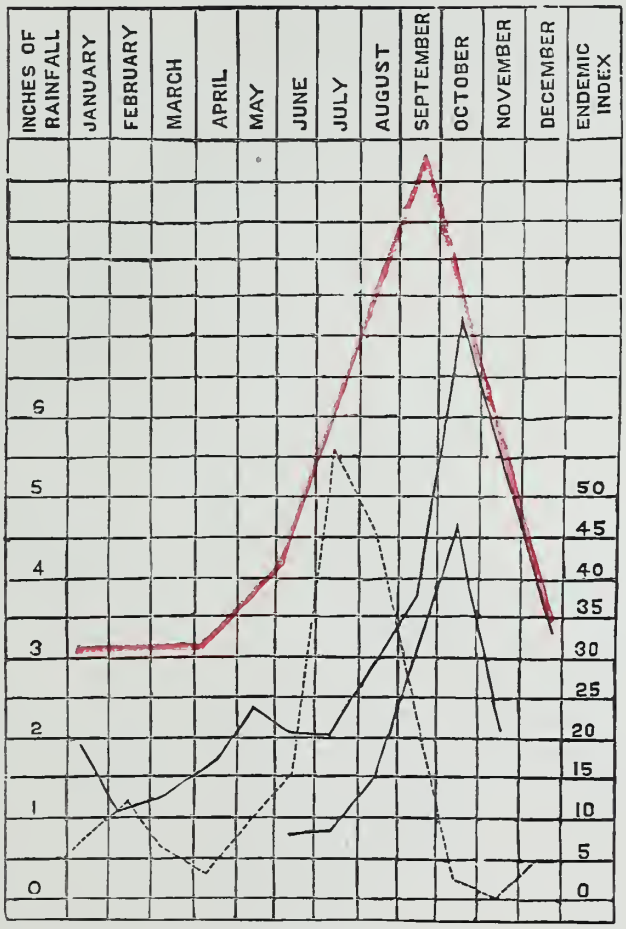


Chart No. II. Red line=curve of *anopheles* mosquitoes. (*A culicifacies* and *A. Rossi.*)
Upper black line=admission rate per 1,000 of British and Native troops (years 1892—1901).
Lower black line=Endemic indices of bazaar children (right hand figures, *vide* table on page 7).
Dotted line=Rainfall.

It will be seen from this chart that the seasonal prevalence of malarial fevers in Mian Mir corresponds very accurately with the prevalence of *anopheles* mosquitoes.*

In 1902 the first *anopheles* mosquitoes (*A. culicifacies*) were found in the houses on May 20th. The first slight rise in the endemic index, *i.e.*, the commencement of the season of new infections, was noted a month later, which (allowing ten days for the parasites to develop to the sporozoite stage in the mosquito and twenty days for the incubation period in man) is the earliest time

* It will be noted on comparing charts I and II that the fever curve is dependent on the seasonal prevalence of *A. culicifacies* rather than on that of *A. Rossi*, for the latter species does not commence to be prevalent until new infections have already begun.

at which new infections could occur. During August, September, and October the abundance of *anopheles* mosquitoes and the endemic index of the bazaar increased together, and in November with the almost sudden disappearance of adult *anopheles* mosquitoes the endemic index quickly fell.

As further illustrating the close connection which exists between the prevalence of malarial fevers in Mian Mir and the presence and relative abundance of *anopheles* mosquitoes, the conditions found in different bazaars and followers' lines may be given in more detail. The inhabitants of these bazaars live in exactly the same class of house, derive their drinking water from the same source, and are exposed to the same climate and temperature. They are in fact under precisely similar conditions except that the bazaars or lines are at different distances from breeding places of *anopheles* mosquitoes. As would be expected, the number of adult insects of this genus that can be caught in the different bazaars and lines varies with the distance from a breeding place. It will be seen from the following table that the prevalence of malaria is least in the lines that are furthest from a breeding place and where consequently fewer *anopheles* mosquitoes can be found, and greatest in the lines that are nearest a breeding place and where a large number of *anopheles* mosquitoes are present.

Table showing the influence of breeding places of *anopheles* mosquitoes on the prevalence of malaria in Mian Mir.

Name of locality.	Distance of nearest breeding place and its character.	Species of *anopheles* found and abundance.	Endemic index.	Spleen rate per cent.
British Infantry Bazaar.	Irrigation watercourse 30 yds. Pools 40 yds.	*A. culicifacies* } Abundant *A. Rossi* } Abundant *A. fuliginosus* } Rare *A. pulcherrimus* } Rare *A. nigerrimus* } Rare	52	80
Royal Artillery Bazaar.	Irrigation watercourse 172 yds. Pools in bazaar.	*A. culicifacies* Not very abundant. *A. Rossi* Abundant *A. Stephensi* } Scanty *A. pulcherrimus* } Scanty	35	75
Syce lines (A) .	Irrigation watercourse 125 yds.	*A. culicifacies* } Abundant *A. Rossi* } Abundant	56	48
Syce lines (B) .	The same watercourse as for syce lines (A), 584 yds.	*A. culicifacies* } Scanty *A. Rossi* } Scanty	20	20

An experiment which I carried out during the year and which will be again

referred to in the account of the operations, also illustrates in a remarkable way how entirely the prevalence of malaria is influenced by the presence or absence of *anopheles* mosquitoes. This experiment was the removal of the inhabitants of the syce lines (A), referred to in the above table, into tents on a new site ¾ of a mile from the nearest irrigation watercourse and 600 yards from any pool. No *anopheles* mosquitoes were ever found in these tents and the result of the experiment was the reduction of the percentage of infected children from 56 at the height of the fever season in 1901, to 4 at the same time in 1902.

Only two forms of the malarial parasite have been met with in Mian Mir, *viz.:* the Benign Tertian and the Malignant Tertian forms. Out of 66 infections occurring in native children 40 were with the Benign Tertian parasite and 26 with the Malignant Tertian. Among the European troops the proportion of Simple to Malignant Tertian infections is greater than this. Out of 18 infections among the men of the Royal Artillery in November 1901, 14 were with the Simple Tertian parasite and 4 with the Malignant Tertian.

No Quartan parasites have been found in Mian Mir.

The foregoing account refers to Mian Mir as a whole, but it was not considered advisable to attempt to deal with so wide an area as the whole cantonment in our experimental operations. The area occupied by the Royal Artillery lines, which are more or less isolated from the rest of the cantonment, was therefore selected, and it is now necessary to add a few details regarding the conditions under which malaria prevails in these lines.

I.— The sources of infection of *anopheles* mosquitoes in the Royal Artillery Lines.

It has already been shown that a high percentage of the young children in the various bazaars and followers' lines are infected with malarial parasites, and as these children receive no treatment whatever, it may be assumed with certainty that they form the chief source from which *anopheles* mosquitoes become infected.*

In the Royal Artillery Lines there are five principal sources of this nature, *viz:*—

(*1*) *The Syce Lines of the Right Battery.* (Fig. 1. A.) The infection of children in these lines is between 50 and 60 *per cent.*, and the distance of the lines from the barracks is 150 yards.

(*2*) *The Hospital followers' lines.* The infection of children in these lines is about 50 *per cent.*, and they are situated within thirty or forty yards of the hospital and prison.

---

*For further reasons of this fact see "Malaria in India," by Captain S. P. James, I.M.S. (Scientific Memoirs by Officers of the Medical and Sanitary Departments of the Government of India, New Series, No. 2), pages 61 and 89.

(3) *The Syce Lines of the Left Battery.* (Fig. 1. B.) The infection of children is 20 *per cent.*, and they are situated 400 yards from the barracks.

(4) *The Royal Artillery bazaar.* The infection of children is 35 *per cent.*, and it is situated 440 yards from the barracks.

(5) *The Servants' quarters in the officers' bungalows.* A large percentage of the servants' children who live in the bungalow compounds are infected with parasites, and they form a dangerous source of malarial infection to the Europeans living in the bungalows.

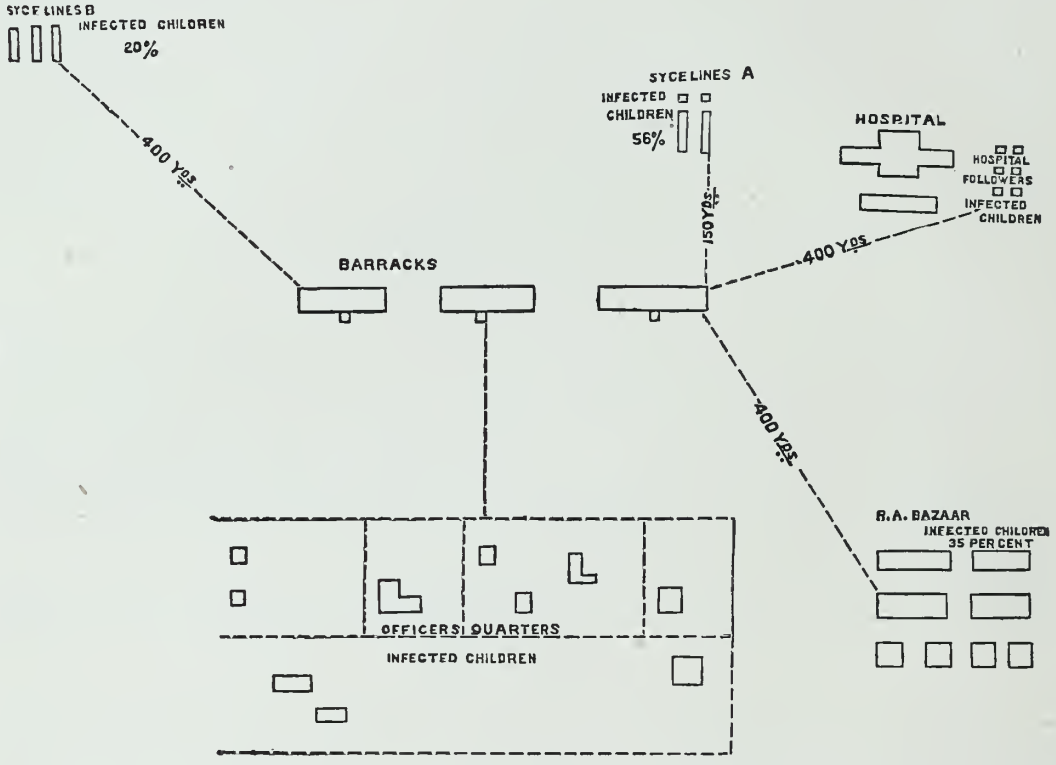
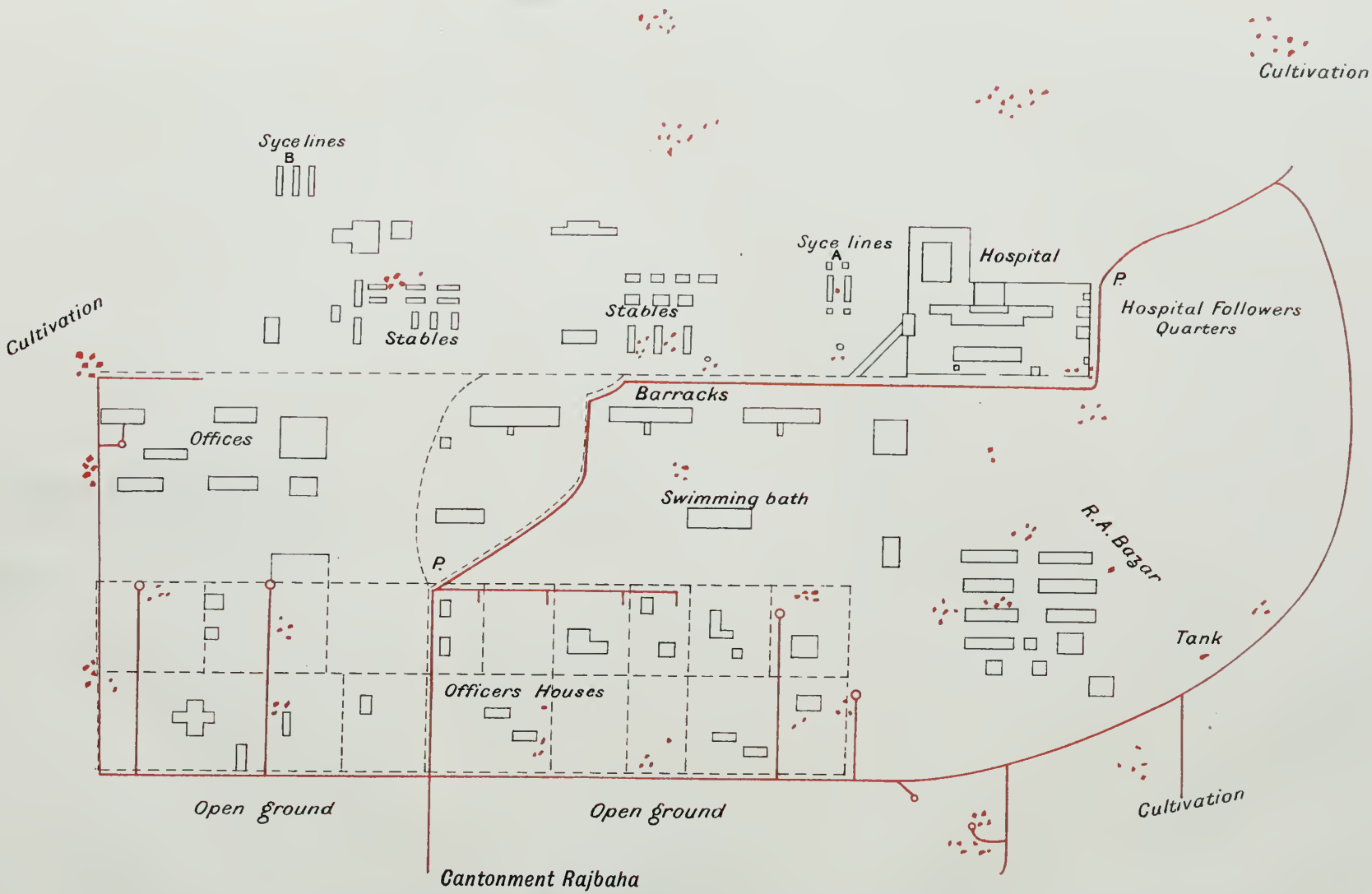


Fig. 1. Showing the chief sources from which *anopheles* mosquitoes become infected in the Royal Artillery Lines at Mian Mir.

II.—The carrier of infection in the Royal Artillery Lines.

All the species of *anopheles* mosquitoes previously mentioned, except *A. nigerrimus*, are found in the Royal Artillery lines. As in other parts of the cantonment *A. Rossi* is by far the most abundant, and enormous numbers of this species can be caught from July to November in the houses of the bazaar and lines, in the barracks, hospital, and prison. *A. culicifacies* is also abundant throughout the lines, and adults of this species can be easily caught in the bazaars and barracks. This is undoubtedly the species by which infection is chiefly, if not entirely, carried in Mian Mir. The other species of *anopheles* mosquitoes referred to, are very rare in the Royal Artillery lines.



A Plan of Royal Artillery Lines at Mian Mir showing the irrigation watercourses and other anopheles breeding places (in red), P. P. the brick lined watercourse.

No 859. Print., India.—Oct. 03.—1,164.

Litho., S I O Calcutta.

The breeding places of anopheles *mosquitoes in the Royal Artillery lines.*

In most stations the breeding grounds of *anopheles* mosquitoes during the rainy season and those during the dry season can be sharply marked off from each other, but owing to the flatness of the ground in Mian Mir, and to its impervious nature, a slight shower of rain produces almost the same conditions as regards the presence of breeding places, as in other districts are produced only during the true rainy season. At almost any time of the year, therefore, numerous rain-formed breeding places may exist in Mian Mir, and it will be better for this reason to enumerate all the places where *anopheles* larvæ have been found at any time during the years 1901 and 1902, indicating at the same time the relative importance of each breeding place. (See plan of Royal Artillery Lines.)

(1) The larger irrigation channels ("*Rajbahas*").
(2) The irrigation watercourses.
(3) Water spread over the gardens and fields for irrigation purposes.
(4) Pools left in the bed of an irrigation watercourse when the supply of water has been cut off.
(5) Pools formed by overflow of the irrigation watercourses.
(6) A few large ponds or "tanks" and a large number of small stone reservoirs for collecting water in the gardens.
(7) Rain-filled pools, surface drains, rain-formed pools on flat areas of ground, etc.
(8) Domestic utensils, *viz.*, tins and buckets of water kept in the lines in case of fire and for other purposes.
(9) The swimming baths.
(10) The small surface drains, which carry off water from the stand-pipes, wells, cook-houses, baths, etc.
(11) The wells.

1. The larger irrigation channels. The velocity of the water in the main canal (*Rajbaha*) bringing water into the Royal Artillery lines is considerable, and except in the comparatively still water near the bridges, larvæ can rarely be found.

2. In the smaller distributing channels, however (irrigation watercourses or "cuts"), which form a network throughout the cantonment, the flow of water is slow and is frequently further impeded by a thick growth of grass and vegetation along the sides of the watercourse.

Many of these ditches also have no outflow, and end in the basin of a Persian wheel, so that the water in them is quite stagnant except during the time that the Persian wheel is working (about three hours daily). All these irrigation watercourses form excellent breeding places and are the main source of *anopheles* mosquitoes, especially of *A. culicifacies*, in the cantonment.

Many larvæ can as a rule be found in them throughout their length, but they are especially numerous in places where grass and weed are growing at the edge, and also at the bridges where the flow of water is checked.

3. The water distributed over the land dries up quickly as a rule, but even in this, dangerous breeding places of *anopheles* mosquitoes are sometimes found. The young trees in Mian Mir are planted along the bed of small distributing ditches, and pools of water are formed round the roots of each tree. These pools are frequently so deep that all the water given to the trees in one day does not dry up before the next supply comes on the following day, and I have frequently found *anopheles* larvæ and pupæ in them. Similar pools are formed in many parts of the gardens of the officers' bungalows owing to the unevenness of the ground. The supply of irrigation water to the cantonment is a very intermittent one, and during the comparatively short period in which it is available, every one endeavours to flood their gardens as much as possible. Owing to the impervious nature of the soil and to the general flatness of the ground, if more water is given to a garden than can all be soaked up in a day, it collects and forms pools in any depressions of the ground. These pools, being replenished daily, may last for ten days or more.

4. When the irrigation water-supply is cut off from the cantonment, many pools are left in the watercourses. The number of larvæ found in these pools varies considerably. In many of them no larvæ can be found, in others, however, larvæ are so numerous that the surface of the pool is almost covered with them. In the winter these pools are of great importance, for during December, January, and February, when the irrigation water-supply is cut off for long periods at a time, *anopheles* larvæ can remain in a resting condition in pools under the bridges until the warm weather comes again. This is in fact the chief, if not the only, means by which some species of *anopheles* mosquitoes can tide over the cold of winter in Mian Mir. During the cold winter months no adult *anopheles* mosquitoes can be found in the houses, but in such pools as these, larvæ are found in a more or less hybernating condition—that is, they do not grow at all, or grow extremely slowly, until the warm weather comes again.

5. Numerous pools are formed by overflow of the irrigation watercourses, and large numbers of larvæ (*A. Rossi*) are found in these. Occasionally from the breaking down of the side of a watercourse a very extensive overflow is made, forming a pond which may last for some months.

6. In the brick-lined tanks for bathing purposes which are found near some of the bazaars, larvæ are rarely present, but there are also a few ponds, the sides of which are not brick-lined, and in these, *anopheles* larvæ are not uncommon. In every garden there are a number of small brick tanks for collecting water for irrigating purposes. They frequently contained *anopheles* larvæ.

7. Rain-formed pools are exceedingly numerous, and it is difficult to realise the difference which even a small shower of rain makes in the aspect of the cantonment. Large ponds of water cover the plain on every side, and for two days after a few hours' rain, evolutions on the Royal Artillery parade ground become impossible. To reach the syce lines of the batteries one has to wade through water for several hundred yards. The whole cantonment is in a similar condition.

Most of these large sheets of water dry up under the hot sun in two or three days, but pools remain in depressions of the ground and in all the surface drains until the next shower of rain. The condition, indeed, is one of the presence of innumerable pools constantly exposed to a hot sun and constantly being replenished with fresh water; a condition eminently suitable for the breeding of *anopheles* mosquitoes. It is not surprising, therefore, that in all these pools and in all the surface drains numerous larvæ are found during July and August.

8. Two large covered-in swimming baths for the troops are present in the Royal Artillery lines. Although these are constantly used by the men, numerous *anopheles* larvæ were found in both the baths during the summer. The baths take about two days to empty and nearly a fortnight to refill, and the water in them is not completely changed more than three or four times during the whole summer.

9. The waste water from the wells, standpipes, cook-houses, and baths is carried off in small brick channels two or three inches deep. In all of these channels *anopheles* larvæ were found at different times of the year.

10. Numerous tins and earthenware vessels of water are kept in the lines in case of fire and for other purposes. They frequently contained large numbers of *anopheles* larvæ.

11. As a rule, *anopheles* larvæ were not found in the wells, but they were present in a few which are only occasionally used.

The above is a brief description of the conditions under which malarial fevers prevail in Mian Mir, and I shall now describe the operations which have been undertaken for their prevention. It should be noted that the primary object of the operations was to test the efficacy of mosquito destruction, and the chief efforts have, therefore, been directed to this end.

In an experiment such as this, it is necessary to have some definite tests by which success or failure can be measured.

1. Tests of a reduction in the number of *anopheles* mosquitoes.

(*a*) *Larvæ.* It can be made evident that though in previous years larvæ were readily found, yet in the year of the experiment they were not so abundant.

(*b*) *Adult mosquitoes.* It is possible for an observer who has regularly collected *anopheles* mosquitoes in any given bazaar or barrack to ascertain with certainty whether they are more or less abundant in the year of operations than in previous years. It is also possible to ascertain whether *anopheles* mosquitoes are more or less abundant in the houses within the area of operations than in those outside it.

2. Tests of a reduction in the amount of malaria.

(*a*) A reduction in the number of admissions for malarial fevers among the troops.

(*b*) A reduction in the percentage of infection with malarial parasites among the troops.

(*c*) A reduction in the amount o malaria in the regimental bazaars as measured by the percentage of children found infected with malarial parasites.

The first of the tests of a reduction in the amount of malaria is probably the least to be depended upon, because hospital statistics may be affected by many causes; still unless it were possible to show a marked reduction in the number of admissions into hospital for malarial fevers, the operations could not be considered successful. The most conclusive test of all would be the reduction of the percentage of infected children in the regimental bazaars. If, as a result of the operations, it could be shown that a marked reduction in the number of *anopheles* mosquitoes, and in the percentage of infected children in the regimental bazaars, had occurred, the success of the operations would be proved.

PART II.

The operations were commenced on the 2nd of April 1902. They may be described under the following headings :—

(1) Operations directed towards the destruction of *anopheles* mosquitoes.

(2) The removal of a number of infected people to a distance from the breeding places of all mosquitoes, and away from the vicinity of the barracks.

(3) Operations directed towards the destruction of malaria parasites in infected individuals by subjecting such individuals to continuous quinine treatment.

(4) The administration of prophylactic doses of quinine to the troops.

I.—Operations against mosquitoes.

In order that all parts of the area chosen (*viz.*, the Royal Artillery lines) might be systematically examined and dealt with week by week, I divided it for the purposes of the work under the following plan :—

(1) The irrigation watercourses, *viz.*, the main irrigation channel and its six chief branches, called respectively the first to the sixth branch, with their offshoots, which supply the whole area of the Royal Artillery lines.

(2) The "Royal Artillery bazaar section" comprising the bazaar and the area surrounding it.

(3) The "Barracks section" comprising the area round the main barracks, the hospital, and prison.

(4) The "Stables section" comprising the area round the stables, syce lines, etc.

(5) The "Gardens section" comprising the area of the officers' bungalows and gardens.

(6) The "Pools section" comprising all the areas containing more or less permanent pools.

One or more of these sections were carefully examined daily in regular order, so that no part of the lines could be left unexamined and unoperated upon for more than a week at a time. It was not possible of course to examine the whole of the watercourses in one day, but by taking one watercourse and the section near it, *e.g.*, the 1st branch and the bazaar section, the same day, and the 2nd branch and the barracks section the next, and so on, the whole of the area could be gone over during the week.

Methods employed.

These were principally confined to operations against larvæ. The methods used in the irrigation watercourses (running water) and in pools and other collections of stagnant water must be described separately.

(1) Methods employed in the irrigation watercourses.

(*a*) It has already been pointed out that the irrigation watercourses form the chief source of *anopheles* mosquitoes (especially of *A. culicifacies*) in the Royal Artillery lines, and that the larvæ are most numerous in these channels wherever any grass or weed is growing at the edges. Experiments which we had made in November 1901 pointed to the fact that if the sides of an irrigation watercourse are cut clean and smooth so that the flow of water is not impeded, and if all grass and weed under which larvæ can shelter is removed from the edges, the number of larvæ found in such a watercourse is greatly diminished. The chief method employed was, therefore, based on this fact, and it was hoped that by constantly keeping the sides of the watercourses smooth and free from grass for many months, they might be made permanently unsuitable for the breeding of *anopheles* larvæ.

(*b*) A more effective and permanent means of carrying out the above principle was to have one of the watercourses lined with brick and smoothly plastered with cement. This was done with a length of watercourse running through the centre of the lines and in front of the main barracks and hospital. (Plan of R. A. lines. p. p'.)

(*c*) For some weeks during June and July I tried the method of drying out and cleaning each branch once every ten days. In this way all the larvæ present in the watercourse were killed before they had time to reach the pupa stage, but on account of the expense of drying out the channels—for most of the water had to be baled out with buckets,—and the fact that the stopping of the water interfered to some extent with irrigation, the method was discontinued.

(*d*) The method of pouring oil on the watercourses.

I have already mentioned that many of the watercourses contain almost stagnant water, and for these the plan of destroying the larvæ with kerosene oil naturally suggests itself.

Some experiments that I made upon a plot of grass-land and *lucerne*, kindly lent me for the purpose by the Officer Commanding the Royal Artillery, showed that even large quantities of kerosene oil poured round the roots of the grass had no injurious effect whatever, nor did it give any bad taste or smell to the

grass; but in spite of these experiments I consider that it would be very inadvisable to use a method from which there would be a danger of any kerosene oil reaching the crops. Nor do I think it would be advisable to use a preparation, such as "larvicide," which colours the water red.

If in any year the crops were poor it would certainly be ascribed by natives, and even by many Europeans, to the use of either of these methods.

With proper precautions, however, it is quite possible in certain places to pour kerosene oil on the watercourses without any of it reaching the land; and on this point my experiments showed the following results :—

(1) Kerosene oil poured on a watercourse between any two bridges does not pass beyond either. This is due to the fact that the bridges over the watercourses in Mian Mir are what are called "syphon bridges," that is the depth of water in the watercourses is always greater than the height of the arch of a bridge, so that, as the oil floats only on the surface of the water, it cannot pass through the arch of the bridge. This is illustrated in the diagram below (Fig. 2) in which it is seen that oil poured on the stretch of water between the bridges A and B cannot pass through the arch D to reach the stretch of water between the bridges B and C.

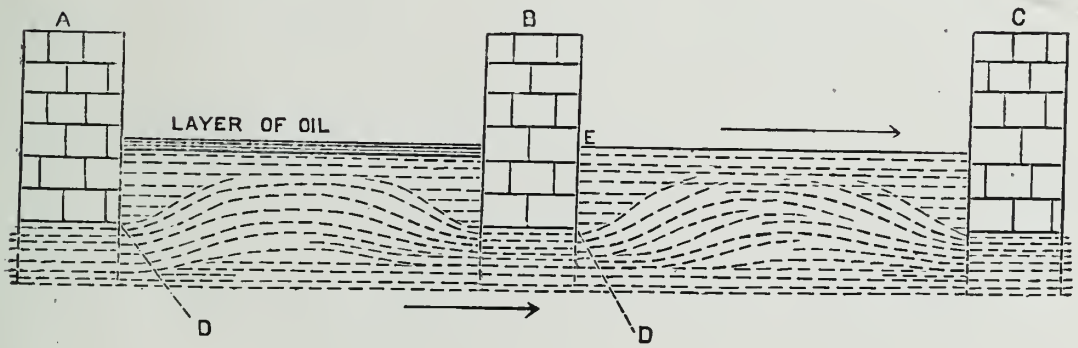


Fig 2.

A, B, C, Bridges over a watercourse. D, Height of arch of bridge. E, water level. The arrows indicate the direction of flow of the water.

(2) For the same reason if a deep board is placed over the mouth of a Persian wheel, half the board being under the surface of the water and half above it, oil can be safely poured on the watercourse without any entering the *jalahar* itself.

(3) The water-supply to the canals is frequently shut off for a week or more at a time. When this is done numerous pools are left in the

watercourses, and while these are drying in the sun, oil may be poured on them with great advantage.

On account of the fact that special precautions are necessary when kerosene oil is used as a larvicide on the watercourses, this method can only be carried out under careful supervision.

II.—Methods employed for pools and other collections of stagnant water.

(*a*) Pools formed in connection with irrigation.

These comprise firstly, large, more or less permanent pools formed from time to time by the overflow of a watercourse or the breaking down of its banks. Such pools were, as far as possible, prevented from being formed by paying constant attention to the watercourses, building up their banks wherever there was danger of overflow, and digging them out in order to keep the water level below the height of the bank. When any such pools had formed they were temporarily covered with a layer of oil and afterwards filled in with earth. Secondly, a number of small pools are formed in the gardens by reason of the fact that all the water given to an area in one day does not always sink in or dry up before the next day's supply of water reaches it. Any small pool formed in this way is replenished daily so that a pool lasting ten or twelve days is formed. In the weekly examinations of the gardens section, pools of this nature containing *anopheles* larvæ were frequently found. As the owners of the gardens might object to kerosene oil being used on land where plants and flowers were growing, the water of these pools was either drained away, or emptied out and thrown over the land. Thirdly, numerous pools are left in the beds of the watercourses after the supply of water is cut off. As a rule, these pools contained many larvæ. By connecting one pool with another throughout the length of a watercourse, it was often possible to dry the whole of these pools quickly; where this could not be done, oil was poured on the separate pools. After the water-supply is cut off a pool also remains in the bottom of each *jalahar*. These pools were dried by emptying out the water with tins and buckets.

(*b*) Rain-formed pools.

These are very numerous during the months of June and July. First there are the large shallow ponds of water formed almost throughout the lines on the level plain after every shower of rain. In the Royal Artillery lines the chief ponds of this nature, are formed on the parade ground, on the football ground, and near the Royal Artillery bazaar. As a rule, these superficial pools dry up in two or three days, but if before the end of that time more rain falls, they remain sufficiently long for larvæ to develop in them. By digging small channels

in various directions it was comparatively easy to drain these away into the irrigation watercourses, and this was done every time rain fell.

More dangerous breeding grounds are formed by the *surface drains* which exist throughout the lines. From the fact that these drains have little or no fall, rain accumulates in them for many days, and after a week or so they swarm with *anopheles* larvæ. Owing to the large amount of water they contain they are difficult to deal with. Some were dried out with buckets, and on others oil was poured. During 1902 the rainfall was a very small one, but in years of heavy rain a great deal of labour would be required to keep these drains free from larvæ.

(*c*) Permanent "tanks" and pools.

One large "tank" near the Royal Artillery bazaar was filled in by the cantonment authorities. Over 250 smaller tanks and pools have been filled in by contract labour.

(*d*) Numerous other breeding places have been dealt with as they have been discovered. The small drains carrying off water from the baths, standpipes, etc., in which larvæ were frequently found, have been swept out regularly, tins and buckets kept full of water in the lines in case of fire have been emptied weekly, as have also the horse troughs and cisterns. The only breeding places which have not been dealt with in any way are the swimming baths. Numerous *anopheles* larvæ were found in the two large swimming baths in August and September. As they take three days to empty and a fortnight to refill, it was difficult to suggest any effective method of preventing them from acting as breeding places.

The following details of the work are taken from my diary during the year.

The operations were commenced under favourable circumstances, for at the end of March no adult *anopheles* mosquitoes could be found by careful search in the houses, and as the irrigation water-supply had been cut off for some time, there were comparatively few breeding places to be dealt with.

The first object was to get all the irrigation watercourses thoroughly cleaned out and their edges made smooth and free from grass and weed. Twenty coolies under a headman of the canal department were engaged, and work on the watercourses was started on the 2nd of April. The fresh supply of water entered the canals on the 9th April, and a very few *anopheles* larvæ were found in them on the 13th and 14th. Some of the watercourses were almost hidden from view by thick pampas grass and branches of trees which grew on their banks, and as it was very necessary that this thick growth of vegetation should be cleared away as quickly as possible, so that the watercourses might be converted into clean channels exposed to the sun and air, it was found desirable

to employ a larger staff of temporary men to carry out this first work. From the 21st of April to the end of the month, therefore, between forty and fifty coolies were employed daily on the irrigation watercourses. By the end of April all the watercourses in the area of the operations had been thoroughly cleaned out, all the grass growing on their banks had been cut down, and their edges had been made as smooth as possible. On the 20th of April the water-supply of the canals was again shut off. As a result of this many pools were left in the watercourses and in the *jalahars*. A few *anopheles* larvæ and numerous *culex* larvæ were found in all these pools. Most of them were dried out by the men with tins and buckets, but as an experiment a few of the pools were covered with a layer of kerosene oil. This killed all the larvæ present in about twenty minutes, but three days afterwards (on the 24th) young *anopheles* and *culex* larvæ were again found in these pools. On the evening of the 24th of April heavy rain fell for some hours. This caused many pools to form throughout the area and gave an indication of what pools would be most dangerous during the rainy season. A map showing the more permanent pools was now made, and additional men employed to commence filling them in with earth. In the meantime the water of the superficial pools was drained away by digging small channels leading into the irrigation watercourses, and, until the more permanent pools could be filled in, they were dried by baling out the water with buckets, and throwing it on the open plain where it would dry quickly in the sun. After all the watercourses had been dealt with for the first time in the manner described, two men were permanently applied to each branch. Their duties were—

(1) To keep the edges free from grass and weed.

(2) To keep the sides smooth and regular by scraping away the earth at some places and filling in any small bays and irregularities at others.

(3) To constantly remove all leaves, sticks, straw, and other floating *débris*. For this purpose the men were provided with shallow round baskets and by walking in the water and scooping the basket along the edge underneath the surface, all the floating *débris* was collected and thrown out on the bank. This was a very important part of their work, for dead leaves were constantly falling into the water from the trees above, and under their shelter larvæ were constantly found. If left alone the leaves collected in a thick mass at each bridge, impeding the flow of water and forming an excellent breeding ground for larvæ.

Two men could in this way go over their own branch three times daily. They were constantly supervised and directed in their work by myself, my hospital assistant, and by an overseer of the canal department.

The irrigation water-supply started again on May 6th and was not shut off for more than two or three days at a time throughout the summer.

In spite of the constant cleaning operations a few *anopheles* larvæ, and a considerable number of *culex* larvæ were found in the watercourses on May 12th. By covering the shallow baskets with muslin the men were able to catch and destroy a good number of these larvæ at the same time as they collected the leaves.

On May 15th the bricking of the watercourse running through the centre of the lines was commenced, and for this purpose the water was shut off from this branch and the others which obtained their supply from it.

On the 14th of May slight rain fell, and the pools formed were treated in the same manner as on the previous occasion. The filling in of permanent pools with earth and the cleaning of the watercourses was continued steadily, but in spite of this, a certain number of *anopheles* larvæ were found in all the watercourses from May 15th onwards. Along the smooth edges they were not, as a rule, to be found, but in many of the watercourses roots of trees projected into the channel, and in their shelter larvæ were generally present. All the larger roots were therefore cut off with hatchets to the level of the bank and so got rid of.

From May 30th to June 3rd inclusive I made careful observations throughout the area of operations and throughout another part of the cantonment to ascertain whether any success in the reduction of the number of larvæ and adult mosquitoes had been attained. The results showed that although in the area of operations a few larvæ could be found in all the watercourses by *careful search*, the number present was far less than in the uncleaned watercourses in other parts of the cantonment. In the watercourses of the British Infantry bazaar for example an enormous number of larvæ were found, and even without dipping with a tin they could be seen among the grass and weed at the edges. It was evident that up to the end of May the breeding of larvæ in the watercourses of the area of operations had been prevented to a very considerable extent. Corresponding success was attained with regard to the number of adult insects to be found in the houses. On June 3rd after careful search for over an hour I could not find a single adult *anopheles* mosquito in the Royal Artillery bazaar. On the same day I caught ten adult *A. culicifacies* in the British Infantry bazaar in about half an hour without much difficulty.

During June, however, the number of larvæ in the watercourses of the area of operations increased considerably in spite of the same methods being continued. I have already mentioned that by reason of some of the watercourses having no outlet, the water in them is stagnant except for about three hours a day while the Persian wheels are working. However clean they are kept, they

form for this reason exceedingly favourable breeding grounds for *anopheles* mosquitoes. Finding that cleaning operations were not completely successful in preventing larvæ from appearing in large numbers in these watercourses, I tried the plan from June 15th of making a "*band*" at the beginning of each branch, emptying out all the water in the branch, allowing it to dry in the sun, and again letting in fresh water [method (*c*) page 20]. By this means all the larvæ present in the branch at the time were killed. During the month of June I found that larvæ required ten to twelve days to develop from the very young stage into adults, and to kill all larvæ it was therefore necessary to dry each branch about once every ten days. I carried out this plan for six weeks, but on account of the expense of drying out the branches, which was done partly by working the Persian wheels and partly by baling out the water with tins and buckets, and the fact that such operations interfered to some extent with irrigation, I ceased it about the middle of July and returned to the method of keeping the edges of the watercourses clean and removing all floating leaves and *débris*.

From the beginning of June the operations carried on, and the results of examinations for larvæ and adults, may be more conveniently described under the headings of the various sections into which the area of operations was arbitrarily divided.

I.—The Watercourses.

In the area of operations there are ten watercourses. As the methods employed and the results obtained were practically the same in all, it will be sufficient to give the details concerning one watercourse only, noting that similar operations were carried out on different dates in all the other watercourses and almost similar results obtained.

The following account refers to the first watercourse through the gardens :—

On the 7th of June a fair number of nearly full-grown *anopheles* larvæ were found in this branch. A *band* was made at its commencement, and it was dried out and cleaned on the 8th. Fresh water was let in on the 9th, but on the 12th very young *anopheles* larvæ were again present. The number and size of the larvæ found, gradually increased, and on the 19th this watercourse contained a good many nearly full-grown larvæ. The water was therefore again shut off on the 20th and the watercourse was dried and the mud it contained dug out. As irrigation was not required from this branch at the time, fresh water was not let in until the 26th of June. Three days later a few very young larvæ were again found. Cleaning of the sides and removal of leaves was carried on daily, but on the 8th July many young *anopheles* larvæ and a few full-grown ones were found throughout its length. On the 9th of July the water was

again shut off and the branch dried, but before the drying was completed the branch was refilled by rain on the 10th, so it was again dried and fresh water let in on the 13th. New broods of larvæ were not found again until the 17th. On the 22nd there was very little water in this branch and numerous full-grown and young *anopheles* larvæ were found in it. As the supply of water was so small that none could reach the Persian wheel, oil was poured on the branch, which killed all the larvæ. Sufficient water for irrigation did not reach this branch again until the beginning of August, and on the 9th of August young larvæ were found. Full-grown larvæ were not found until the 22nd, when this branch had again become so shallow as to form only a series of pools. These pools were dried out. With the return of the irrigation water-supply cleaning operations were carried on daily, but in spite of this very many full-grown larvæ and innumerable young ones were again found on the 31st of August. With proper precautions to prevent any oil reaching the Persian wheel [see method (*d*) page 20], I therefore covered the whole branch with a layer of kerosene oil. On the next day no larvæ at all were found. The good effect of the oil lasted about a week; on the 7th of September young *anopheles* larvæ were again found and on the 15th numerous full-grown larvæ. With the same precautions as before, oil was again poured on the first half of the branch on the 17th of September, and on the 18th no larvæ were found, except a few at the very end where the oil had not reached. On the 24th of September a few very young larvæ were again found (the effect of the oil having passed off) and on the 28th when the branch was so shallow as to form only a chain of pools, full-grown larvæ were present. These pools were dried out. At the beginning of October the irrigation water-supply was cut off and this branch was dry throughout its length on the 3rd of October. The supply re-commenced on the 9th of October and young larvæ were found on the 14th. On the 22nd it contained many full-grown larvæ and some pupæ, but on this date the irrigation-supply was again cut off, so that on the 23rd this branch contained only a few pools which were easily dried out. On the 24th of October fresh pools were formed by rain, but on the 27th no larvæ were found in these pools and they were dry on the 28th. The irrigation-supply was resumed on the 5th of November, but it only ran for three days, and on the 11th with the exception of some pools under the bridges, this branch was dry throughout. A few young *anopheles* larvæ were found in these pools. They were dried out, and together with all the other watercourses this one remained dry until the irrigation water-supply was again given on the 29th of November. This branch had now been dry for fully twenty days, and as at this time no adult *anopheles* mosquitoes could be found in the houses, it afforded a good opportunity of testing whether any adults were really present, though none could be detected by careful search, or not. If adult *anopheles* mosquitoes were present in the houses,

it is reasonable to suppose that they would again lay their eggs in the branch as they had done throughout the year. No young larvæ were, however, found in this or in any of the other branches from the time of arrival of fresh water on November 29th up to the end of the winter. On December 5th the irrigation supply was again cut off and a chain of pools left in the branch. These were allowed to dry in the sun, and afforded exceedingly favourable breeding places, but no eggs or larvæ appeared in them or in the pools of any of the other branches.

A few details may now be given regarding the watercourse which was rendered permanently smooth and free from weed and grass, by lining it with bricks plastered with cement. The total length of the bricked portion is 4,985 feet. Before being bricked, it formed an exceedingly dirty weed-grown ditch containing almost stagnant water, running through the centre of the lines and within a few yards of the front of the barracks, the military prison, and the hospital. In addition to its being a favourable breeding ground of *anopheles* mosquitoes, it formed the depositing-ground for most of the old tins, bottles, and rubbish of all descriptions from the lines and barracks. As a result of the bricking it has been converted into a clean-flowing channel about five feet wide and four feet deep, running with moderate velocity and in an efficient manner. A sliding door has been placed at its commencement by means of which the flow may be regulated and the channel flushed out. The bricking was commenced on May 15th and completed at the end of July.

Although from a sanitary point of view the bricking of this watercourse has been of great benefit, the result from the point of view of destruction of *anopheles* breeding grounds has not fully realized our expectations. We had hoped that after bricking this channel the flow of water in it would be sufficiently swift to entirely prevent its acting as a breeding place. This, however, is not the case, and, if left entirely alone, it still remains as a breeding ground of *anopheles* mosquitoes, though not nearly to the same extent as formerly.

This is due partly to the fact that the flow of water is still only very moderate, and partly to the numerous leaves which, falling into the water from the trees above, collect at the bridges and form a suitable shelter for larvæ.

During part of August I did no cleaning operations whatever on this watercourse with the object of testing the efficacy of the work of bricking. Although no larvæ could, as a rule, be found along the clean plastered sides of the channel, they were numerous at the bridges and under the leaves. After this I constantly employed two men with baskets to take out all the leaves and to keep the sides of the channel clean and free from mud. As a result of this the number of larvæ to be found was very much diminished, and it may fairly be said that, while the water is actually running, one or two men constantly employed in this way could keep this bricked watercourse almost completely free of *anopheles*

larvæ. When the irrigation water-supply stops, however, a number of pools remain in this watercourse as in the unbricked ones, and these would also require constant attention.*

The above descriptions may be taken as fair examples of the methods employed and the results obtained in all the watercourses of the area of operations. It will be seen that though various plans were carefully tried, it was not possible to prevent *anopheles* larvæ constantly appearing in the watercourses in large numbers. By continuous efforts it is possible to check the breeding to a certain extent, and to kill a great many of the larvæ, but if the measures are stopped for even a week at a time, the condition becomes almost the same as it would be had no operations at all been carried out.

II.—The Royal Artillery Bazaar Section.

On the 11th of June no breeding places except the irrigation watercourses were found in this section. On the 17th a few *anopheles* larvæ were found in a garden pool in front of the bazaar. This pool was dried out and on the 22nd no breeding places were found. Search for adults was frequently made during June. On the 3rd no adult *anopheles* mosquitoes were found after careful search in many of the houses, stables, and sheds. On the 16th after nearly an hour's search I found four adult *A. culicifacies* in one of the stables. By the 26th the number of *A. culicifacies* present in the houses had increased considerably, but they were still scanty and difficult to catch. This was in marked contrast to other bazaars in the cantonment where from the beginning of the month adult insects (*A. culicifacies*) were present in sufficient numbers to be caught without much difficulty in many of the houses. No adult *A. Rossi* were caught in any of the bazaars during June.

During July a large number of rain-formed breeding places were found from time to time in this section. These consisted chiefly of large and small pools formed by holes dug for road-making, building, and other purposes. Along one roadside there were twenty pools averaging five feet long by two feet deep, which after a short time swarmed with the larvæ of *A. Rossi*. Such pools were temporarily covered with a layer of oil and afterwards filled in with earth. The surface

* Experience has shown that this channel was constructed on an entirely wrong plan. Instead of simply digging out and bricking the old watercourse as was done in this case, a very narrow channelwith straight sides should have been built in the bed of the old one, and the fall in this channel should have been sufficient to prevent any water standing in it when the supply was turned off at the head. If it should eventually be decided that all irrigation channels in cantonments should be made *pucca*, the first principle to be kept in view should be to raise the water at its source from the main irrigation canal to such a height that it will run swiftly through all parts of the cantonment in very narrow bricked channels with such a fall that when the water is turned off at the head, all the channels will dry up completely. I am informed that this plan is quite practicable in Mian Mir and that it would do away with all Persian wheels, syphon bridges, etc., irrigation being carried on by "flow" instead of by "lift."

The simple bricking of a channel without some such provision as this for ensuring a swift running stream, is of little avail.

drains in this section were found also to afford excellent breeding places for *anopheles* mosquitoes, and during this month it required great care to keep them free from larvæ. Another class of breeding place found during this month were the drains and pools formed by the waste water of the wells. This waste water of wells is difficult to deal with, for it cannot be drained away on account of the levelness of the ground. In this section it was dealt with by collecting it in a deep pool, which was kept constantly covered with a layer of oil. During July, in spite of constant attention being paid to all breeding places, the number of adult mosquitoes (*A. culicifacies* and *A. Rossi*) found in the houses, increased considerably, and towards the end of the month specimens of both species could be caught fairly easily at any time.

During August the chief breeding places in this section were the roadside surface drains, the deep pools of the roadsides, the drains carrying off water from the wells and from the bazaars, a few irrigation pools in a garden in front of the bazaar, and the *gumlahs* of water kept outside each house. During part of the month the road in front of the bazaar was being relaid. In road-making it is the practice of the contractors to use the surface drain, which runs at the side of the road they are laying, as a reservior of water. One end of the drain is closed by a barrier of bricks and earth, and the drain is then filled with water for use in their work. A collection of water fifty yards or more in length is thus made, which quickly becomes swarming with *anopheles* larvæ. Within the limits of the cantonment the practice of filling these drains with water was stopped with some difficulty, as the workmen refused to continue laying the roads unless it was allowed. Outside the cantonment limit it was still carried on, and the constant emptying out of the water in these drains every few days required much labour. In the absence of urgent work of this kind my men were employed filling in the roadside pools with earth. In the meantime all pools were kept covered with a layer of oil.

In this month it was found necessary to repeat the oiling of pools *at least every three days* as the larvæ developed so rapidly, and under the great heat the oil quickly evaporated.

During the month of August a very large number of *A. Rossi* were present in the houses of the bazaar. The number of adult *A. culicifacies* had also increased somewhat, though they were not by any means as plentiful as *A. Rossi*, nor were they so common as in other bazaars of the cantonment where no operations had been carried on.

During September and October the same class of breeding places had to be dealt with. Most of the pools had by this time been filled in with earth, and, as the rains had almost ceased, the work was less. Constant inspection, however, was necessary to keep larvæ from appearing in every collection of water in and round the bazaar. Tins and other receptacles of water had to be constantly

emptied, shallow drains to be swept out, and a layer of oil kept constantly on overflow pools of the wells and other collections of water that could not be dealt with in any other way.

During September the filling in of a large pond near the bazaar was completed by the cantonment authorities.

At the beginning of September there was a temporary diminution in the number of adult insects to be found in the houses, but at the end of the month and during October their numbers were certainly as great, if not greater, than during August. A few specimens of other species, *viz.*, *A. Stephensi*, *A. pulcherrimus*, and *A. fuliginosus*, were also found during September. During November the development of larvæ was less rapid and the number to be found in the different breeding places gradually diminished. A progressive decrease in the number of adult *anopheles* mosquitoes to be found in the houses also occurred, and at the end of this month it was difficult to catch a specimen of either species. At the beginning of December no adult *anopheles* mosquitoes of any kind could be found in the houses, and from this time onwards no fresh batches of larvæ appeared in any of the breeding places.

A similar disappearance of adults and larvæ was, however, noted in other parts of the cantonment where no operations had been carried on.

III.—The Barracks Section.

On June 4th, *anopheles* larvæ were found in the shallow drains carrying off water from the swimming baths and in the overflow water of the stand-pipes. A sweeper was appointed to keep all the shallow drains in the vicinity of the barracks swept out daily. On the 14th, *anopheles* larvæ were found in shallow pools near the Persian wheel of the 4th barrack and in its stone water-reservoir. On the 24th, *anopheles* larvæ were found in a number of kerosene oil tins which were kept full of water near No. 8 Barrack, and on the 30th larvæ were found in the stone water-reservoirs of the cook-rooms. Adult *anopheles* mosquitoes (*A. culicifacies*) were first found in the barracks on June 16th. Throughout the month, however, the number of adult insects in the barracks was very small. No *A. Rossi* were caught in the barracks during June. During July, rain-formed breeding places were abundant in this section; all the storm-water surface drains especially formed good breeding grounds for *A. Rossi*. After each shower of rain also, large areas of water collected in many parts of the lines, and a number of deep trenches which had been made to mark off the boundary of the cantonment grass-farm area, also became filled with water, which in two or three days swarmed with larvæ. The shallow collections of surface water were drained away into the irrigation canals. Collections of water in pools, drains or trenches, were either emptied out or covered with a layer of oil.

The number of adult insects found in the barracks increased quickly during this month. On July 8th large numbers of *A. Rossi* were collected from the barracks and harness rooms, and on the 11th these rooms also contained a fair number of *A. culicifacies*. Throughout the month, however, the number of adult *anopheles* mosquitoes present in the barracks and other parts of this section was not nearly so great as in the parts of the cantonment where no operations had been carried on.

The following is a list of the places where *anopheles* larvæ were found in this section during August :—

(1) Numerous waste water pools from stand-pipes, cook-houses, and wells.
(2) Small brick drains leading away from the above.
(3) Numerous rain-formed pools in the surface (storm-water) drains and on the open plain.
(4) Tins of water kept near the barracks and hayricks in case of fire.
(5) The swimming baths.

These breeding places (except the swimming baths for which no method could be devised), were dealt with regularly. During the month the number of adult *anopheles* mosquitoes present in the barracks increased considerably.

The breeding places during September and October were similar to those in August and had to be regularly dealt with ; the section being gone over weekly for this purpose.

The number of adult insects to be found in the barracks was greatest during these two months.

During November the number of adults and larvæ gradually diminished, and by the end of the month no adults could be found and no fresh batches of larvæ appeared in any of the breeding places.

IV.—The Stables Section.

This section is an extension of the previous one, and as it contained a similar class of breeding places, it is unnecessary to record the operations regarding it in detail. It should be mentioned, however, that during August *anopheles* larvæ were found on several occasions in two wells in this area which were not often used. The level of the water in these wells was about thirty feet from the surface.

V.—The Gardens Section.

The diary regarding this section is chiefly a record of numerous breeding places formed in the gardens of the officers' houses as the result of irrigation or of rain. From the commencement of the operations the surroundings of each bungalow were carefully examined at least once a week and all breeding places dealt with. Several of the officers themselves assisted in doing away with all breeding places in their compounds. In spite, however, of constant

attention to all breeding places, adult *anopheles* mosquitoes could always be found in the bungalows and in the servants' quarters. In several of the compounds as many as twenty pools containing *anopheles* larvæ would be found at each examination, as well as small drains, iron cisterns, and the stone water reservoirs which are present in the garden of every Indian bungalow, and although all these breeding places were effectively dealt with at each examination, in less than a week they had nearly all re-formed and become again swarming with larvæ. One of the most difficult breeding places to deal with in this section was the waste water from the garden wells, which caused a small marshy area to form round the well in which *anopheles* mosquitoes bred freely. Wherever possible this water was drained or swept away, but in most compounds frequent application of oil was all that could be done.

Other difficult breeding places to deal with in this section were the pools of water round the road-side trees.

As these pools are replenished daily by a fresh supply of irrigation-water, before they have completely dried up, they form favourable breeding places.

VI.—The Pools Section.

It is unnecessary to enter into detail regarding the numerous rain-formed pools which had to be dealt with during the months of June, July, and August. The following extract from my diary will, however, give some idea of the number of pools formed by a rainfall of a few hours' duration on July 27th :—

"On the 28th July as the result of two hours rain yesterday the following pools which will remain sufficiently long for the development of larvæ were found in the area :—

(1) 40 pools beyond the hospital.
(2) 12 ditches surrounding grass-land beyond the hospital.
(3) 24 pools about three feet deep, and three large ones about four or five feet deep, beyond the syce lines.
(4) 21 smaller pools, which will probably dry up in three or four days between the syce lines and the barracks.
(5) 6 very large pools and 8 smaller ones, at the rifle butts. (The large pools are about 12 yards long by 10 yards wide and about four feet deep.)
(6) 5 large pools, 3 smaller ones, and two ditches near the Persian wheel of the fourth watercourse.
(7) 2 large pools near the east part of the fifth watercourse.
(8) 5 large shallow pools in the Royal Artillery Bazaar, 10 of the same kind near the Right Battery stables, and 3 near the Left Battery stables.

(9) A group of large pools near the Police guard.

(10) 22 deep road-side pools behind the Royal Artillery Bazaar."

In addition to these, most of the surface drains were full of standing water and innumerable small pools and broad collections of water covered the area on every side. Rain fell again on the 1st and on the 3rd of August, so that even the smaller pools had no opportunity of drying up for a week or more. Large numbers of *anopheles* larvæ were found in all these pools, and even in the broad shallow collections of water on the open plain, as early as two days after their formation. As soon as a pool was found to contain larvæ it was covered with a layer of kerosene oil, or dried out, and marked to be filled in with earth.

By the end of October over 250 of the larger sized pools had been filled in with broken bricks and earth.

The above is a brief account of the operations against mosquitoes carried out during the summer of 1902. The greater part of the work of filling in pools and emptying out water from the surface drains was done by contract labour, so as to avoid the necessity of constantly watching the coolies to see that they were working properly, thus leaving myself and my hospital assistant more time for searching for new breeding places. Work of this kind is also done much more quickly and less expensively by putting it out on contract than by employing a large number of coolies on a stated daily wage. My object was as far as possible to deal permanently with each breeding place as it was found, so as to avoid having repeatedly to deal with the same breeding place. This, however, can only be done with a limited number of permanent pools, and the chief difficulty met with in Mian Mir arises from the fact that the bulk of the breeding places require constant and regular attention throughout the summer.

I.—Operations during the winter of 1902 and the spring of 1903.

I have already mentioned that the number of larvæ to be found in all the breeding places and the number of adult insects present in the houses gradually decreased during November until by the end of the month I was not able to find any adult insects in the houses and no new batches of *anopheles* eggs or larvæ appeared in any of the breeding places. It was necessary to find out whether the disappearance of adult *anopheles* mosquitoes was complete or whether a certain number still remained in the houses in a "hybernating" condition throughout the winter ready to lay their eggs when the warm weather came again in the spring. During December and January I made experiments to test this point. In the first place I allowed all favourable breeding places in the area to remain untouched during December. If any adult female *anopheles* mosquitoes were really present in the houses, it was almost certain that some of them at least would

occasionally come to the pools and lay their eggs as they had always done during the summer, for the nights during December were not invariably cold. During December, however, not a single *anopheles* egg or young larva was found in any of the breeding places in the area of operations. This was strong evidence that all adult *anopheles* mosquitoes had disappeared from the area. Further proof was afforded by the following experiments. Having chosen a house in which abundant adult *anopheles* mosquitoes had been constantly found during the summer, I covered the floor with sheets, and having carefully closed all the outlets, four or five cones composed of a mixture of nitrate of potash, charcoal, sulphur, and pyrethrum powder were burnt in the house for two hours. During the summer I had proved that two of these cones burnt in a house of the same size were sufficient to kill all the mosquitoes in it. In December, however, not a single dead *anopheles* was found on the sheets spread on the ground. This experiment was repeated in a number of houses, stables, sheds, arches of bridges, and other places where it appeared probable adult *anopheles* mosquitoes might hybernate through the winter. Numerous *culex* mosquitoes (which were very plentiful in December and January, and regularly laid their eggs in the breeding places), were killed by this method, but no *anopheles*. I conclude therefore that all insects of the latter genus had disappeared from the area or died from the cold by the beginning of December. It was necessary now to ascertain whether this disappearance was a natural one or whether it was due to the operations. Control observations were therefore made in a part of the cantonment where no operations had been carried on and in a village (Shadara) about six miles from Mian Mir where permanent breeding places of all kinds were abundant.

The results of these observations which were made in January and the beginning of February were as follow :—

(1) No adult specimens of *A. culicifacies* or *A. Rossi* were found (even by the method of burning cones) in parts of the cantonment where no operations had been carried on, or in Shadara.

The result of these observations was therefore the same as that of the observations within the area of operations.

(2) In recently formed pools at Shadara no larvæ of *A. culicifacies* or *A. Rossi* were ever found, thus confirming the first observation.

In *permanent* breeding places which had remained from the summer without drying up, larvæ of *A. culicifacies* could still be found throughout the winter. These larvæ were in a more or less "hybernating" condition ; their movements were sluggish and they grew extremely slowly if at all. None were seen to develop into pupæ and it seems probable that they cannot do so until the warm weather comes.

Even in these old pools, however, no larvæ of *A. Rossi* were found.

(3) In Shadara a fair number of adult specimens of *A. fuliginosus* and a few *A. pulcherrimus* were found in the houses throughout the winter.

Both these species are at all times very rare in the Royal Artillery lines and it is not surprising therefore that in the winter none should be found there, though they were present in the village of Shadara.

(4) Eggs, young larvæ and pupæ of *A. fuliginosus* and *A. pulcherrimus* were found in new breeding places formed during the winter in Shadara though no larvæ of *A. culicifacies* or *A. Rossi* were found in these pools.

The only adult *anopheles* mosquitoes which were found in Shadara did not, therefore, hybernate in any sense of the term, but carried on their usual habit of laying eggs which developed into pupæ and adults even in the coldest months of winter.

It is evident from the above observations that *as regards the Punjab* all species do not tide over the winter by the same methods. *A. fuliginosus* and *A. pulcherrimus* live through the winter continuing the same habits as in the autumn. The adult insects of *A. culicifacies* completely disappear or die off during the winter but some larvæ of this species remain alive in permanent breeding places in a more or less "hybernating" condition until the warm weather comes again. Both adults and larvæ of *A. Rossi* disappear entirely from the Punjab during the winter, and do not return again until the end of June or the beginning of July, some time after *A. culicifacies* has already become fairly prevalent.*

The observations appeared to show that *A. culicifacies*, the carrier of malaria in Mian Mir, is able to tide over the Punjab winter solely by means of "hybernating" larvæ, and it was therefore my object during the winter months to kill off all such larvæ within a wide distance of the area.

As no new batches of eggs were being laid in the breeding places this was not a very difficult task. Daily expeditions were made in every direction from the centre of the lines, so that the ground was covered in ever widening circles and no pool or collection of water of any kind was left unoperated upon. At the same time the experiments of burning pyrethrum cones or *neem* leaves in the houses of the area were continued, as I wished to leave no margin for errors of observation in the previous experiments. For a number of these experiments I used dried *neem* leaves instead of pyrethrum cones as it was difficult to obtain a sufficient supply of the latter. During the summer I had found that *neem* leaves

* The observations concerning the complete disappearance of adult specimens of *A. culicifacies* and *A. Rossi* and the persistence of adults of *A. fuliginosus* (in the form of an interesting "winter variety") have been confirmed by Major Adie, I.M.S., at Ferozepore.

are quite efficacious in killing mosquitoes, if a sufficient quantity is used; and their employment has the additional advantage of not being disliked by natives. After a large number of houses in the bazaar and syce lines had been treated in this way with a negative result, it became apparent that this part of the work was unnecessary, and it was discontinued at the end of February. By the end of this month all larvæ had been killed off within a radius of nearly two miles from the outer limits of the area and I had convinced myself that no adult insects were present in the houses. Throughout March no larvæ or adults were found in any parts of the area.

Throughout the winter a few adults and larvæ of *A. fuliginosus* and a few "hybernating" larvæ of *A. culicifacies* were found in the village of Kora $2\frac{1}{2}$ miles from the area, and during March the number of *A. fuliginosus* adults and larvæ in this village increased considerably. In April the first adult *A. culicifacies* were noted in this village and soon afterwards the number of larvæ and adults of this species increased considerably. In the area, however, none were found. At the end of April it was noticed that larvæ of *A. culicifacies* were being washed down into the area along the irrigation canals from places outside; and it was evident that this was one way at least by which *anopheles* mosquitoes could re-appear in the area. Soon afterwards the first adults of *A. culicifacies* were found in the houses of the area, but up to May 15th a daily examination revealed the presence of only a few adults which it was supposed had developed from larvæ washed in by the irrigation canals. No larvæ of *A. fuliginosus* had been detected anywhere in the area up to this time. On making the usual examination of the harness-rooms on May 16th, however, I was surprised to find numerous adults of *A. fuliginosus;* on almost every saddle four or five specimens were seen. On searching the bazaar the same condition was noted; almost every house contained specimens of this species. As the majority of those caught were full-grown females distended with eggs, it was evident that they were not newly hatched; and as the nearest place where adult *A. fuliginosus* had been previously found was the village of Kora, it must be assumed that they had come into the area from this village, a distance of $2\frac{1}{2}$ miles. This observation, taken in conjunction with others made last year in the district round Lahore, convinces me that at certain times of the year *anopheles* mosquitoes are able to traverse comparatively long distances. This opinion also receives support from the fact that the unusual prevalence of *A. fuliginosus* in the Royal Artillery lines lasted only a few days. Within a week it was again impossible to find a single specimen of this species in the houses of the area, and no trace of their passage through the lines remained.

This direct flight over a comparatively long distance is, I think, quite distinct from the third method by which *anopheles* mosquitoes reached the area in the spring, *viz.*, the gradual spreading of mosquitoes in all directions from an area in

which they are very abundant. Such a gradual invasion of a new area results from the fact that all newly hatched mosquitoes do not return to the house or village from which their parent came, but fly to houses in the opposite direction; and having found their food there, proceed to breeding pools still further removed from the original village. A gradual invasion of the Royal Artillery lines by adult *A. culicifacies* occurred in this manner from surrounding villages where no operations had been carried on, but which were connected with the lines by isolated houses and breeding places.

There is still a fourth method by which *anopheles* mosquitoes reach the area from outside, *viz.*, by being conveyed in carriages, carts, and other vehicles from neighbouring towns and villages. This method was one of daily observation in our work during 1901 and 1902.

When all these methods are taken into consideration, it is not surprising that in spite of the vigorous operations during the winter, *anopheles* mosquitoes (*A. culicifacies*) were again almost as prevalent in the area at the end of May as they had been at the beginning of the previous year's work. As in the previous year, however, no *A. Rossi* or its larvæ had been found in the area or in surrounding villages up to this time, and if the seasonal prevalence of this species during the present year is similar to that of last year they cannot be expected until the end of June or the beginning of July.

It will be apparent from the results just recorded that the destruction of *anopheles* mosquitoes in Mian Mir is a task which must be repeated every year.

II.—The removal of a number of people to a distance from all breeding places of mosquitoes.

It was not our original intention in Mian Mir to test the value of any method of getting rid of malaria except that of the destruction of *anopheles* mosquitoes, but when I found that this might be a task of great difficulty, I thought it advisable to make an experiment which would, if successful, conclusively prove that if the presence of *anopheles* mosquitoes in a place can be entirely eliminated, malaria will quickly disappear.

As we had already shown that the further a group of houses is removed from a breeding place the fewer are the adult insects present, my plan was to remove all the inhabitants of one series of syce lines to such a distance from all breeding places that no *anopheles* mosquitoes at all should be present in the houses on the new site. In Mian Mir the dry open plain extends for several miles in some directions, and it was not difficult therefore to find a site sufficiently far removed from all irrigation canals and pools. The people chosen for the experiment were the inhabitants of the first series of syce lines (plan of R. A. lines, A).

These syce lines were situated within 140 yards of an irrigation watercourse

and contained about 78 children, 56 *per cent.* of whom had malaria parasites in their blood in October 1901. In August 1902 I caused all the inhabitants (men, women, and children) of this series of syce lines to be moved into tents on a site $\frac{3}{4}$ of a mile from the nearest irrigation watercourse and over 600 yards from the nearest pool. As a result of this no adult *anopheles* mosquitoes were found in any of the tents during September and October of the year of operations. In every other respect, however, these people were under precisely the same conditions on the new site as they had been on the old, except that, being in tents, they were more exposed to the sun and rain than they had been in their houses on the old site. The result of this experiment is given in Part III (page 44).

This experiment also afforded an opportunity of testing to a certain extent the practicability of the method of "segregation of Europeans" recommended by Stephens and Christophers in Africa, in that by the removal of this large source of infection of *anopheles* mosquitoes, one of the chief dangers to the men in barracks was effectually done away with.

III.—Operations directed against malaria parasites in infected individuals.

In addition to the experiment described above, I thought it advisable to test the practicability of a modification of Professor Koch's method of getting rid of malaria by the systematic treatment of all infected people with quinine.

I have already mentioned that the native children in the different followers' lines and in the Royal Artillery Bazaar form the chief source from which *anopheles* mosquitoes become infected. It was desirable therefore as far as possible to do away with the effect of these large sources of mosquito infection. With regard to the first dangerous source of infection (the first series of syce lines) this had already been done by their removal to a distance. The other method by which the same result might possibly be attained was by the systematic treatment of all children with quinine; and on account of the expense and inconvenience which would arise from the permanent removal of the syce lines to a distance of half a mile or more from the barracks, it was very important to ascertain whether the plan of the systematic treatment of children was a practicable and effective one.

The second dangerous source of infection of *anopheles* mosquitoes was afforded by the children in the hospital followers' quarters, which are situated at the back of the hospital compound about 40 yards from the hospital and the prison and about 400 yards from the main barracks of the troops. It was found impracticable to have the hospital followers and their families moved into new quarters at a distance from the hospital, and I decided therefore to treat all the children regularly with quinine. They numbered 34 in all. The treatment was commenced on August 30th and each child received a dose of from five to ten

grains of quinine according to age,* once a day for the first ten consecutive days and afterwards, irrespective of age, a dose of ten grains of quinine twice a week throughout September, October, and November. In the middle of October when, in spite of the treatment, a few new infections occurred among the children, ten days' consecutive treatment was again given to those children in whose blood parasites were found, and again at the end of November when the season of new infections had passed, all the children were again given ten days' consecutive treatment in order to completely kill off any parasites which might still have resisted the previous treatment.

It was found that even children of one or two years of age could stand a daily dose of ten grains of quinine without any ill effect. After the first three or four days most of the children took the quinine readily and apparently got to like the bitter taste.

The third source of infection of *anopheles* mosquitoes in order of importance, was the second series of syce lines.

The children of this series of syce lines, which are situated at a distance of 400 yards from the nearest barrack, were infected with malaria parasites to the extent of 20 *per cent.* in October 1901. From the 10th of September to the end of November 1902, they were regularly treated with quinine in the same manner as was being done with the hospital followers' children. They numbered 103 in all, and each child received a daily dose of from five to ten grains of quinine for the first ten days, and afterwards a dose of ten grains twice a week on consecutive days.

The results of these measures are given in Part III (pages 45 and 46).

The fourth important source of infection of *anopheles* mosquitoes was the Royal Artillery bazaar. This bazaar was selected as a favourable one for testing the efficacy of the operations against mosquitoes, and for this reason no measures other than mosquito destruction were carried out in it.

IV.—Prophylaxis by the administration of quinine to the troops.

In addition to the measures described above, all the British soldiers in the cantonment received a dose of ten grains of quinine twice a week on consecutive days. The chief object of this measure was to prevent relapses of old infections. We had found that at the end of November 1901, 22·2 *per cent.* of the men of Royal Artillery who were doing their duty and who were apparently quite healthy, had malaria parasites in their blood, so that it was evident some measure by which relapses of these infections might be prevented was necessary.

The administration of quinine was commenced on April 18th and continued throughout the summer. In order to ensure the prophylactic dose being taken by the men they were paraded twice a week at the hospital and the quinine given under the supervision of a medical officer.

* Children up to five years of age received a dose of five grains; beyond that age a dose of ten grains.

PART III.

Results.

In considering the results of the operations up to the end of May 1903, the results obtained with regard to the prevalence of *anopheles* mosquitoes may be taken first.

On this important point the following conclusions must, I think, be admitted:—

(1) The operations were commenced in 1902 under favourable conditions, for very few, if any, adult *anopheles* mosquitoes were present in the houses and very few, if any, larvæ in the breeding places.

(2) In spite of the operations the number of adult *anopheles* mosquitoes present in the houses and the number of larvæ found in the breeding places gradually increased month by month to a maximum in September and October, and then quickly decreased during November and the beginning of December although the operations were discontinued during the latter month. A similar disappearance was also noted in places where no operations were carried on.

(3) As a result of the operations the increase in the number of *anopheles* mosquitoes which occurred each month was to a great extent checked, so that the actual number present in the houses at any time of the year was not nearly so great as it would have been had no operations been carried on.

(4) In spite of the check on the breeding of *anopheles* mosquitoes the actual number present in the houses from July to November (1902) was such that specimens of both species *A. culicifacies* and *A. Rossi* could be caught fairly easily at any time.

(5) The number of adult specimens of *A. culicifacies* present in the houses of the area was less than in other parts of the cantonment where no operations had been carried on.

(6) The number of adult specimens of *A. culicifacies* present in the houses during the year 1902, was less than during the preceding year. This cannot be said with certainty regarding parts of the cantonment where no operations had been carried on. In the British Infantry Bazaar, for example, if any difference between the number of *A. culicifacies* present in the houses during 1901 and 1902 existed, it was so slight as not to be detectable by searching. In the Royal Artillery Bazaar, on the other hand, the difference between the two years was quite apparent to one who had regularly searched the bazaar during both the years of observation.

(7) The number of larvæ of *A. culicifacies* to be found in the cleaned

canals was certainly less than in the uncleaned ones, and for this reason less than could be found during the preceding year.

(8) Regarding *A. Rossi* it cannot, I think, be said with certainty that the number of adult insects present in the area was less than in other parts of the cantonment, nor was it, to any appreciable extent, less than during the preceding year. In all parts of the cantonment during both years this species was so abundant that any difference which existed was negligable. Except on the supposition that they came from some place outside the area of operations, it is very difficult to account for the almost sudden appearance of large numbers of this species at the beginning of July. It is also difficult to account for the fact that in spite of all breeding places of this species within the area (which extended to a distance of nearly half a mile in every direction from the houses where the adult insects were caught), being regularly dealt with, the number of adult insects present in the houses increased considerably instead of diminishing.

(9) During the winter all *anopheles* adults had, as far as could be ascertained by careful search and experiment, entirely disappeared from the area, and all larvæ were killed off within a radius of nearly two miles in every direction from its outer limits. In the spring, however, *anopheles* larvæ and adults re-appeared in the area and at the end of May, 1903, *A. culicifacies* was almost as prevalent as it had been at the same time in the previous year.

(10) For a few days during May, 1903, the area was flooded with numerous adult *A. fuliginosus*, which apparently came from the village of Kora, $2\frac{1}{2}$ miles away, and which disappeared almost as suddenly as they had come.

It is evident, therefore, that the problem of materially reducing the number of *anopheles* mosquitoes in Mian Mir is a difficult one. The chief difficulty arises from the fact that the majority of breeding places are such that they cannot be permanently done away with, and it seems doubtful whether any operations short of *permanent* extermination of all possible breeding places will produce a marked reduction in the number of *anopheles* mosquitoes. It should be remembered, however, that the operations have only been in progress one year, and that by continually rendering all possible breeding places inhospitable for larvæ, a permanent diminution may in time be effected.

Secondly we may consider whether any reduction in the amount of malaria has been effected, and if so, the means by which this has been brought about. The tests of a reduction in the amount of malaria are, in order of importance:—

(1) A reduction in the amount of malaria in the regimental bazaars as measured by a reduction in the percentage of children found infected with malaria parasites.

(2) A reduction in the number of admissions for malarial fevers among the troops.

(3) A reduction in the percentage of infection with malaria parasites among the troops.

I.—The amount of malaria in the Regimental Bazaars.

(*1*)—*The Royal Artillery Bazaar.*

In this bazaar mosquito destruction was the only prophylactic measure carried out.

The percentage of infection of the children and their spleen rates at the height of the fever seasons in 1901 and 1902 are shown in the following table.

	Royal Artillery Bazaar.	
Date	October 1901.	October 1902.
Percentage of infected children	35	20
Percentage with enlarged spleens	75	64

In the year of operations, therefore, there was a reduction in the amount of malaria in this bazaar. It should be noted, however, that in the British Infantry bazaar where no operations were carried out and in which, for this reason, control observations were made, a reduction in the amount of malaria also occurred during 1902. This is shown in the following table:—

	British Infantry Bazaar.	
Date	October 1901.	October 1902.
Percentage of infected children	52	42·3
Percentage with enlarged spleens	80	69

It may be assumed, therefore, that a reduction in the percentage of infected children of the Royal Artillery Bazaar would also have occurred in 1902, in the ordinary course of events, and in the absence of any operations. A closer examination of the figures shows, however, that over and above the decrease which would have occurred in 1902 in consequence of the year being an unusually healthy one, there was an additional decrease which may fairly be ascribed to the operations against mosquitoes. The decrease which occurred in the British Infantry Bazaar in the absence of any operations is represented by the proportion as 1·23 : 1, and the decrease in the Royal Artillery Bazaar where mosquito

destruction was carried on, is represented by the proportion as 1·75 : 1, a much greater decrease than can be accounted for solely by the fact of the year being an exceptionally healthy one.

The difference between the relative decrease of the spleen rates in these two bazaars is not so marked, being represented by the proportions as 1·159 : 1 in the British Infantry Bazaar and as 1·171 : 1 in the Royal Artillery Bazaar, respectively, but this may be accounted for by the fact that in places where there are a large number of chronically enlarged spleen cases, even in the entire absence of new infections, it takes many months for the spleen rate to diminish very markedly.* The difference between the percentage of infected children in these two bazaars in September was much greater than in October and it is reasonable to conclude from the following table that the onset of the season of greatest liability to infection had, as a result of the operations against mosquitoes, been delayed, and that the season had been shortened in the Royal Artillery Bazaar.

Table showing the percentage of infected children during some months of the years 1901 and 1902 in the Royal Artillery Bazaar and in the British Infantry Bazaar, respectively.

	Oct. 1901.	Nov. 1901.	Dec. 1901.	Apl. 1902.	June 1902.	July 1902.	Aug. 1902.	Sept. 1902.	Oct. 1902.	Nov. 1902.
Royal Artillery Bazaar .	35	†	29	21	5	4	4	4	20	12
British Infantry Bazaar .	52	22	†	†	8·3	8·5	15	32·2	42·3	27

We may fairly conclude, therefore, that purely as the result of a reduction in the number of *anopheles* mosquitoes (*A. culicifacies*), a reduction in the amount of malaria in this bazaar occurred. We have already seen that the reduction in the number of *anopheles* mosquitoes in this bazaar was not very marked, though it was quite apparent to one who had regularly searched the bazaar during both the years of observation. Had it been possible to have effected a still greater diminution in the number of *A. culicifacies* (the carrier of malaria in Mian Mir) there is little doubt that the amount of malaria would have been reduced to a far greater extent. *The experiment shows that even a slight reduction in the number of* anopheles *mosquitoes affects the amount of malaria to an extent which is quite measureable.*

(2)—*The first series of syce lines.*

The operation carried out with regard to the inhabitants of these lines was their removal into tents on a new site.

* See "Malaria in India" (Sc. Memoirs New Series No. 2) page 93.
† Not examined.

The results of this experiment were very striking. The old site was situated within 140 yards of an irrigation watercourse, in which numerous *anopheles* mosquitoes (*A. culicifacies*) were breeding, and many adult insects of this species were present in the houses in October 1901. At that time 56·5 per cent. of the children were found infected with malaria parasites. The new site was situated on the open plain, $\frac{3}{4}$ of a mile from the nearest irrigation watercourse and over 600 yards from the nearest pool. As a result of this no adult *anopheles* mosquitoes were found in any of the tents during September and October of the year of operations, not a single case of fever occurred among the adults throughout the season, and on October 24th (the height of the fever season) parasites were only found in one child out of twenty-five examined. That is, by their removal from the vicinity of *anopheles* breeding places and without treatment of any kind, the percentage of infection of these children had been reduced from 56·5 in October 1901 to only 4 in October 1902. Their spleen rate also had decreased from 75 *per cent.* in April 1902 to 60 *per cent.* in October 1902.

This experiment proves that if it is possible to do away entirely with breeding places of *anopheles* mosquitoes in any place, malaria quickly disappears. It has already been mentioned that in every respect other than proximity to breeding places of *anopheles* mosquitoes, this body of people were under the same conditions on the new site as they had been on the old, except that being in tents they were more exposed to the sun and rain than they had been in their houses on the old site.

(3)—*The Hospital followers' lines.*

The measure carried out in these lines was the treatment of all the children with quinine. These children were not examined in October 1901, but judging from the fact that in June 1902 (the month in which malarial fever is least prevalent in Mian Mir) 60 *per cent.* of the children had enlarged spleens, it is reasonable to conclude that had they been examined during the fever season of 1901, a large proportion would have been found infected. In the middle of August before quinine treatment was commenced, I found parasites in two out of twenty-five children examined. The treatment was commenced on August 30th and on September 15th I was unable to find parasites in slides from any of twenty-five children examined, nor again in the same number examined on October 6th. On October 24th, however, I found parasites in four children out of twenty-five examined, that is at the height of the fever season 16 *per cent.* of the children were infected in spite of the treatment. These new infections, however, were quickly cured by daily treatment for 10 days, and I consider that this source of infection of *anopheles* mosquitoes was minimized, if not entirely eliminated. Probably a certain number of mosquitoes became infected from these children before the treatment was commenced, and another year it would be advisable to

begin the treatment earlier in the season. The effect of the treatment on the spleen rate is shown in the following table :—

	To show the effect of quinine treatment on the Hospital followers' children (total number—34).						
	Aug. 30th.	Sep. 9th.	Sep. 29th.	Oct. 6th.	Oct. 20th.*	Nov. 4th.	Nov. 24th.
Total number with enlarged spleens.	18	13	12	9	13	12	8

* The height of the fever season.

(4) *The second series of syce lines.*

Quinine treatment was also carried out on the children in these lines.

At the height of the fever season in October 1901, 20 *per cent.* of these children had been found to be infected with malaria parasites. As a result of the quinine treatment no parasites were present in any of 25 children examined in October 1902. The effect on the spleen rate is shown in the following table :—

	To show the effect of quinine treatment on the children of the syce lines (total number—103).					
	Oct. 1901.	Sept. 1st, 1902.	Sept. 29th.	Oct. 15th.*	Nov. 15th.	Nov. 25th.
Percentage with enlarged spleens .	20	15·5	2·5	4·9	3·9	1·9

II.—The number of admissions for malarial fevers among the troops.

It is generally agreed that the year 1902 was an exceptionally healthy one for all troops in the Punjab, and for this reason it was an unfavourable year for testing the efficacy of prophylactic measures by means of hospital statistics. The number of admissions for ague among British troops throughout the cantonment of Mian Mir was, I understand, the lowest ever recorded in this station.

* The height of the fever season.

The following tables have been furnished me by the Senior Medical Officer, Mian Mir:—

TABLE I.

STATEMENT OF THE ADMISSIONS AND DEATHS FROM MALARIAL FEVERS AMONG THE BRITISH TROOPS AT MIAN MIR FOR THE FIVE YEARS FROM 1898 to 1902.

Years.	Strength.	Admissions.	Deaths.	Ratio per 1,000.	
				Admissions.	Deaths.
1898	869	702	1	808	1
1899	853	400	1	469	1
1900	814	878	2	1,079	2
1901	808	1,094	1	1,354	1
1902	731	197	1	269	1

As shown on page 5 the average annual admission rate per 1,000 for ague in Mian Mir is 663 and the rate of only 269 for all malarial fevers (ague 264 per 1,000 + remittent fever 5 per 1,000) during 1902 compares very favourably with this.

TABLE II.

STATEMENT SHOWING SEPARATELY THE ADMISSIONS AND DEATHS FROM MALARIAL FEVERS AMONG THE BRITISH INFANTRY AND THE ROYAL ARTILLERY IN MIAN MIR FOR THE YEARS 1900—1902.

Years.	Corps.	Strength.	Admissions.	Deaths.	Ratio per 1,000.	
					Admissions.	Deaths.
1900	Royal Artillery	259	132	1	509	4
	British Infantry	555	746	1	1,344	2
1901	Royal Artillery	225	346	1	1,538	4
	British Infantry	583	748	...	1,283	...
1902	Royal Artillery	172	66	...	384	...
	British Infantry	559	131	1	234	2

TABLE II.—*Statement showing the number of admissions for malarial fevers into the British Infantry and Royal Artillery hospitals monthly during 1902.*

BRITISH INFANTRY HOSPITAL.

	Jan. 1902.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly strength.	690	651	667	507	335	321	308	306	314	893	955	601
Admissions . .	15	19	13	5	10	4	3	0	0	31	25	7

ROYAL ARTILLERY HOSPITAL.

	Jan. 1902.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly strength.	*	*	98	311	298	287	276	267	272	263	*	*
Admissions . .			4	5	4	8	1	1	2	12†		

* The regiment was absent from the station.

† Several of these admissions were chronic malarial cases transferred from hill stations. Others were cases contracted on the line of march to Delhi.

TABLE IV.—*A comparison of the admissions for malarial fevers during the years 1901 and 1902.*

HOSPITAL.	Year.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
British Infantry	1901	144	61	67	35	61	53	15	32	46	58	116	65
	1902	15	19	13	5	10	4	3	0	0	31	25	7
Royal Artillery .	1901	20	2	3	6	38	33	22	42	44	75	40	16
	1902	*	*	4	5	4	8	1	1	2	12	*	*

* The regiment was absent from the station.

It is evident from these tables that during the year 1902 the prevalence of malarial fevers among the troops in Mian Mir as shown by statistics was remarkably small. It is difficult to determine accurately the factor to which most credit should be given for this great decrease in the admission rate. In the first place the year 1902 was, as a whole, far more healthy than 1901. Regarding this we have the figures for the British Infantry bazaar as an indication of the difference between the two years. At the height of the fever season in 1901, the endemic index of this bazaar was 52 and the spleen rate 80 *per cent.* At the same time in 1902 the endemic index was 42·3 and the spleen rate 69 *per cent.* There was certainly, therefore, a marked difference between the two years, but not, in my opinion, a difference sufficient to account for the large decrease which occurred in the admission rate of the British Infantry. A large proportion of the immunity enjoyed by these regiments, therefore, must be attributed to the prophylactic issue of quinine (which this year was carried out under strict supervision), for no other prophylactic measure than this was carried out in the British Infantry lines. In former years it has been usual to issue the quinine in bulk from the hospital to a non-commissioned officer of

the regiment, and no control was exercised to see whether the men took the dose or not. It is probable that not one man in ten ever took the quinine, for very few European soldiers will take quinine, if they can possibly avoid doing so, being in this respect far more difficult to deal with than natives. During 1902, however, all the troops were marched to the hospitals twice a week, and the quinine was given under the supervision of a medical officer.

To this fact, therefore, I attribute in large measure the low admission rate for malarial fevers among the British Infantry.

At any rate as regards the statistics of the British Infantry hospital also, a certain margin must be allowed for errors in diagnosis. I am informed that during 1901 it was the rule to admit every case of "fever" at once, and return it as "ague." During 1902, much greater care was taken in diagnosis, and it is even possible that in the British Infantry hospital some cases, which were really cases of malarial fever, were returned under some other heading; for it is difficult to believe that during August and September not a single case of malarial fever should have occurred among over 300 men, at a time when the endemic index of the regimental bazaar was increasing rapidly, (15 *per cent.* in August and 32 *per cent.* in September), and when, from the reports of British officers living in the lines, a large number of native servants were suffering from malarial fever.*

The events which happened in 1902 render it very difficult to form a correct estimate from hospital statistics of the efficacy of the operations of mosquito destruction and of the other measures carried out in the Royal Artillery lines. These events were the arrival of a second regiment into the British Infantry lines at the beginning of October, and the departure of both batteries of Royal Artillery to Delhi at the end of that month. At the most important time of the year, therefore, the statistics of the Royal Artillery were rendered valueless, because after about the 4th of October any man of the Royal Artillery who was attacked with malaria on the line of march to Delhi was returned to Mian Mir and admitted into the hospital there. Mian Mir was in fact kept as a sick depôt to which the men who fell ill on the line of march were returned. For this reason the statistics for men of the Royal Artillery during November show 9 admissions for malarial fever out of a strength of 54 and during December 16 admissions out of a strength of 47. The inclusion of these figures in the annual return has made it appear that the ratio of admissions per 1,000 among

* Seventy-eight admissions into the station hospital at Mian Mir during 1902 were returned as having been due to congestion of the liver. The number is considerably larger than in any previous year on record and it is very probable that in ordinary years many of these cases would have been returned under the heading of ague. The monthly numbers of cases returned as congestion of the liver were: 0 in January, 1 each in February and March, 7 in April (after the commencement of the ante-malaria operations), 6 in May, 9 in June, 28 in July, 13 in August, 6 in September, 7 in October, and 1 in November. It may also be mentioned that there were 34 cases returned as simple continued fever during 1902 as compared with only 1 in 1901.

the Royal Artillery was greater during 1902 than that among the British Infantry. (Table II. Ratio of admissions of Royal Artillery 384 per 1,000; of the British Infantry 234 per 1,000.)

Where so many factors affect the statistics it is in fact impossible to obtain any results of value from their consideration. It is, however, a matter for congratulation that although during 1900 and during 1901 the death rate for malarial fevers among the Royal Artillery was higher than among the British infantry, during 1902 the results are reversed in favour of the Royal Artillery. (Table II.)

I regret that from want of time I have been unable to carry out the third test, *viz.*, the examination of films of blood from a large number of men in the British Infantry and Royal Artillery respectively in order to ascertain whether a reduction in the percentage of infection of the troops themselves has taken place.

A few words may be added regarding the respective value of the different methods of prophylaxis attempted in Mian Mir.

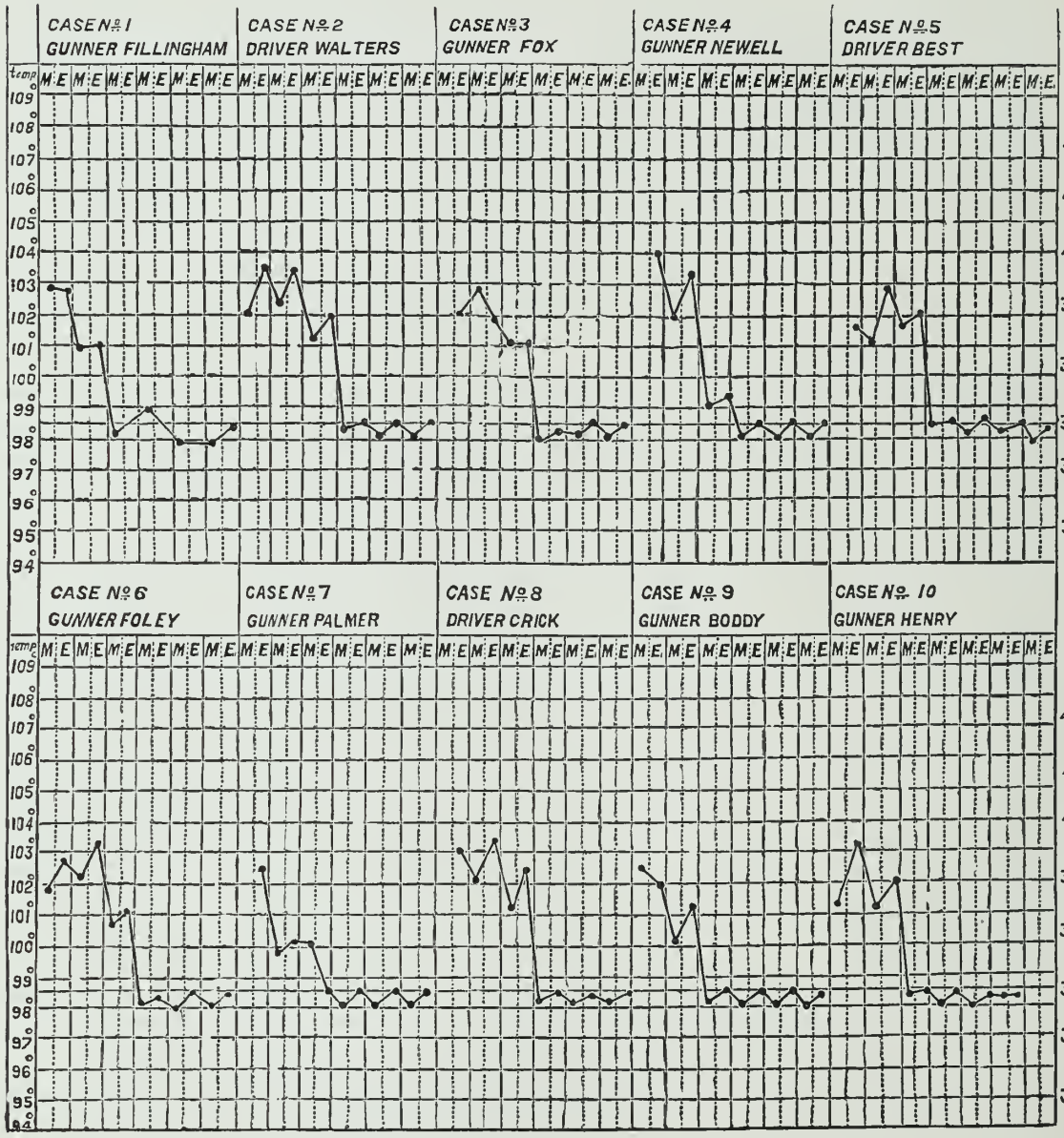
That mosquito destruction, if it can be carried out successfully, will effectually banish malaria, is I think sufficiently proved by the results obtained in the Royal Artillery Bazaar and in the first series of syce lines. Even though it was not possible to reduce the number of *anopheles* mosquitoes very markedly in the Royal Artillery lines, a decrease in the amount of malaria in the Royal Artillery Bazaar greater than can be accounted for by reason of the year being an unusually healthy one, occurred, which can only be attributed to the operations against mosquitoes. In the syce lines (which by their removal were taken entirely out of the range of *anopheles* mosquitoes) malaria almost entirely disappeared. The chief drawback to mosquito destruction is its difficulty and expense. It must be admitted that although we have been given, practically speaking, a free hand in matters of expenditure and in the amount of labour employed, and although my own services and those of a hospital assistant have been confined exclusively to this work, we have, up to the present, made but little impression on the number of *anopheles* mosquitoes. It remains to be seen what the results of the second year's operations, will be, but unless a more marked reduction in the number of *anopheles* mosquitoes can be effected this year than during the previous one, it would, I think, be inadvisable to continue operations on these lines in Mian Mir during a third year.

I attribute great value to the other operations carried on, *viz.*, the attempt to lessen the effects of obvious sources of infection of *anopheles* mosquitoes in cantonments, and it is, I think, of some importance to have shown the practicability of the method of treating large numbers of native children regularly with quinine. This is a measure which requires no special knowledge and one which is applicable to every place where large bodies of native children are gathered together in the vicinity of European troops. One of the features of

the year was the marked freedom from attacks of malaria of the adult syces in the Royal Artillery lines. No statistics are available regarding these men, but the fact was apparent to all the officers in the Royal Artillery. During 1901 all the adult syces received a prophylactic dose of ten grains of quinine twice a week, but I am informed that, in spite of this, great difficulty was frequently experienced in getting the work done, on account of the large number of syces incapacitated by fever. During 1902, however, *although none of the adult syces received a prophylactic dose of quinine*, scarcely a single case of fever occurred among them throughout the year. I attribute this almost entirely to the continued and systematic treatment with quinine of the children (who are undoubtedly the chief source of infection) and in the case of the first series of syce lines to their removal to a place where no mosquitoes could be found.

APPENDIX A.

Charts of some cases of fever admitted into the Royal Artillery Hospital at Mian Mir in which repeated examinations failed to show the presence of malaria parasites and which recovered without quinine treatment. Such cases are, however, frequently returned in hospital statistics as ague.



APPENDIX B.

Rough statement of expenses incurred for the anti-malarial operations at Mian Mir (up to October 31st, 1902).

No.	Item.	Amount.		
		R	*a.*	*p.*
1	Wages of coolies at As. 4 each per day	711	..	...
2	Filling pools—work done by contractors (202,601 cubic feet) .	596	4	2
3	Unwatering pools—work done by contractors	194	12	...
4	Brick-lining and plastering watercourse—total length 4,985 feet.	5,364	14	6
5	Contingent expenses for kerosene oil, materials, etc. about	350	...	...
	TOTAL RUPEES .	7,216	14	8

No. 6.

NEW SERIES.)

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA.

FIRST REPORT OF THE ANTI-MALARIAL OPERATIONS AT MIAN MIR, 1901-1903.

BY

CAPTAIN S. P. JAMES, M.B. (LOND.), I.M.S.

(*On Special Duty.*)

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA.

CALCUTTA:

OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.

1903.

Price 12 Annas or 1s. 2d.